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Commercial / Institutional Buildings

Electrical Energy Technology Study

Prepared for Ontario Ministry of Energy
by
Engineering Interface Limited
and
Marbek Resource Consultants Limited

February, 1988

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Ontario
Ministry of Energy
Robert C. Wong
Minister

Energy leadership
for economic strength

COMMERCIAL/INSTITUTIONAL BUILDINGS

ELECTRICAL ENERGY TECHNOLOGY STUDY

EXECUTIVE SUMMARY

This report is concerned with electrical energy use in Ontario's commercial and institutional buildings. Which types of buildings consume the most electrical energy? Which types of equipment are the largest users? What opportunities exist for energy conservation and efficiency improvements in these buildings? Which new technologies can improve efficiency, and decrease the demand for electric power? What steps can the Ontario government take to help improve the efficient use of electrical energy in these buildings?

The policy of the government of Ontario is that electricity conservation and efficiency improvements will be the major priority in planning to meet the province's future needs for electrical services.

Commercial and institutional buildings in Ontario consumed a total of 31,300 gigawatt-hours* of electrical energy in 1984, representing 27% of Ontario's total consumption. With their operation primarily on week-days, and their high demand for motors, lighting, and cooling, commercial and institutional buildings represent a large fraction of Ontario's peak demand for power, which exceeds 22,500 megawatts*. As Ontario's economy grows, the energy and power demands of commercial and institutional buildings are expected to grow, both in absolute terms, and in proportional terms, relative to all other sectors.

Electricity conservation and efficiency in commercial and institutional buildings can reduce both total energy use and peak power demand in Ontario. The need for new generating stations and transmission lines can be eliminated or deferred. Total energy costs to the consumer can be reduced. Acid rain from coal-fired generating stations can be reduced. At the same time, Ontario can continue to enjoy a comfortable and prosperous standard of living.

Rationale and Methods

The Ministry commissioned this study to assist in planning the development, demonstration, and promotion of efficient electrical energy technologies.

The report identifies and quantifies the major uses of electrical energy in Ontario's commercial and institutional buildings. Which types of equipment consume how much electrical energy per year, in which types of buildings?

*"giga"-10^9
"mega"-10^6

The report then identified eighteen promising new technologies for further study, based on the highest potential for reduction of annual energy consumption and peak power demand, and the lowest simple payback to the consumer, in terms of energy savings.

Each of the promising new technologies was examined, for the following information, in each type of building:

- Potential Annual Energy Savings
- Potential Peak Power Demand Savings
- Current and Potential Penetration Rate into the Current and Future Building Stock
- Load Factor
- Applicability to Current and Future Building Stock
- Barriers to Implementation
- Economics
- Government/Utility Incentives, and their Effect on Potential Savings

The report contains a concise Technology Profile for each new technology, describing the technology, and summarizing key information.

A relational database model was developed to determine the potential savings, in annual energy consumption, and in peak power demand, from each new technology, in each type of building, with and without government/utility incentives. The model categorized all factors required to calculate the energy savings and peak power reductions.

The report describes the calculation procedure which created the relational database.

Results

The eighteen new technologies judged by the consultant to be the most promising involve cooling, lighting, and motors, and total electrical energy use.

The six best technologies, in terms of potential annual energy savings and peak power demand savings, in the year 2000, are the following:

Technology	Potential Savings, Without Incentives		Potential Savings, With Incentives	
	Annual Energy Savings GWh	Peak Power Demand Savings MW	Annual Energy Savings GWh	Peak Power Demand Savings MW
Screw-In Fluorescent Lights	309	99	501	160
Energy Management Control Systems	287	70	513	125
Energy Efficient Fluorescent Lamps	177	52	355	103
High Efficiency Light Fixtures	111	32	297	86
Variable Speed Drives	103	21	359	78
Air Balancing	45	11	447	105

These estimates reflect the results of analysis documented in the study, and judgments made by the study team.

The potential savings from these technologies are not necessarily additive. For example, the potential energy saving from converting a light fixture to high efficiency would be reduced, if an energy management control system turned the light off, during the periods when the light was not required.

Office buildings and retail stores are the types of buildings with the highest potential for electrical efficiency improvements. Both types of buildings are growing in energy use faster than the provincial average.

The factors used in calculation of the energy savings represent the best estimate by a highly experienced consultant. Changing the factors would change the calculated energy quantities, but would not alter the significance of the results. The relational database model is designed to facilitate sensitivity analysis by recalculating savings for various scenarios of assumptions.

The consultant recommends a program of initiatives by the Ontario government and/or the electrical utility, to encourage the adoption of energy efficient technology. These initiatives include demonstration projects, information programs, changes in codes and standards, incentives for energy service companies, innovative lease arrangements, and rebate programs. The consultant recommends an emphasis on new buildings, rather than existing buildings. New buildings and major renovations of old buildings are projected to be 46% of the commercial building stock in 15 years time.

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1.0 REPORT SUMMARY

1.1 Introduction

This section of the report provides the background to the study, describes the approach used and indicates how the report is structured.

1.1.1 Background and Purpose of the Study

The Ministry of Energy is interested in identifying technologies which show the most promise for electrical energy savings in the Ontario commercial and institutional sectors over the next 10 to 15 years. The Ministry has retained Engineering Interface Ltd. and Marbek Resource Consultants Ltd. to develop profiles for some of these technologies, to determine the barriers that might prevent or slow their use, and to estimate the energy and economic impact that they might have on energy use in Ontario.

The Ministry intends to use the profiles developed in this study for three purposes:

1. To identify those technologies most likely to make a major impact on electrical energy use in the commercial sector;

2. To assist in the forecasting of the demand for energy in Ontario; and

3. To identify opportunities for strategic conservation measures in Ontario.

The scope of this report is confined to electrical conservation measures. An attempt was made to select measures with the best potential for strategic conservation.

A total of eighteen electrical conservation measures were selected for detailed review in this report.

1.1.2 Approach Taken In the Study

The following approach was taken during the study to develop the technology profiles for each conservation measure:

(1) Sources of information were identified.

(2) Current energy use and trends in energy use in the Ontario commercial and institutional sectors were analyzed.

(3) Priority fuels, end-uses and technologies were identified.

(4) An overview of the opportunities and barriers associated with each technology and the sector as a whole was prepared, addressing the following areas:
   - the technical potential of each priority technology in terms of maximum energy savings;

- the applicability of each technology in each type of commercial or institutional building (e.g. the fraction of lamps that are already or could be replaced by fluorescent);
- the market penetration of each technology in the commercial/institutional sector in terms of either the fraction of sales or fraction of those in place;
- the impact of each technology in terms of amount of Ontario energy savings and economic impact;
- variations between new and existing and between large and small building types.

(5) A relational database was designed to include an end-use breakdown of Ontario commercial/institutional energy use, a description of each technology and factors for maximum energy savings, applicability and penetration. A Lotus 123 model was prepared to estimate energy savings for each type of building under different assumptions for penetration rate.

6) Individual profiles for each priority technology were prepared containing the following:

- Classification
- Line drawing
- General description
- Specifications
- Energy savings
- Payback period
- Field experience
- Applicability to each building subsector
- Barriers to utilization
- Current market penetration
- Future market penetration under status quo (market) and intervention conditions
- Variations between new and existing buildings and large and small buildings as appropriate
- Potential impact on energy use in Ontario.

A brief overview of other emerging technologies that might have an impact on the Ontario commercial/institutional sector when commercialized is also provided.

(7) The individual impacts of the priority technologies were summarized and an estimate made of the combined impact of the technologies.

(8) An overview of the potential economic impacts of the priority technologies was prepared.

(9) The policy and program implications of the study were reviewed and the steps necessary to use the technologies as strategic conservation measures were identified.

1.1.3 Report Organization

This report is organized as follows:

Section 2 provides an overview of the Ontario commercial and institutional sectors, and identifies priority fuels, end-uses and technologies.

Section 3 provides an overview of opportunities and barriers associated with each priority technology.

Section 4 contains the individual profiles of each priority technology.

Section 5 summarizes the energy savings that might be achieved with the priority technologies, reviews their potential economic impact and discusses the policy implications.

Source material is listed in the Bibliography and attached Appendices contain selected examples from Ontario field experience and a description of the relational database used in the study.

2.0 OVERVIEW OF COMMERCIAL/INSTITUTIONAL SECTOR

This section provides an overview of energy use in the Ontario commercial/institutional sector, including breakdowns of energy consumption by end-use for each subsector (type of building) and identification of priority end-uses. The end-uses considered are cooling, heating, lighting, hot water, motors, and others. A priority end-use is one where significant savings in energy can be achieved in the commercial sector.

2.1 Description of Sector

An estimate of the breakdown of energy consumption in 1985 by end-use and fuel type in the Ontario commercial/-institutional sector is given in Table 1.2. An estimate of total fuel consumption by subsector is given in Table 2.2. The estimates shown in Tables 2.1 and 2.2 were developed from work carried out by Marbek Resources Consultants for the Ministry of Energy in 1986. This work included developing end-use coefficients (energy use per unit floor area) for each subsector and multiplying them by the amount of floor area for existing and new buildings, using appropriate assumptions for fuel mix and conversion efficiency. Appendix A shows a modified version of the Marbek results (set up on a Lotus 123 spreadsheet) showing; (1) floor areas for total and new stock in each subsector; (2) end-use coefficients, fuel shares and conversion efficiencies for stock surviving from pre-1980 in 1985 and new stock built between 1980 and 1984; and finally (3) the breakdown of 1985 energy consumption by end-use, fuel and subsector in all buildings that is reproduced in Tables 2.1 and 2.2. Each of the end-use coefficients shown in Appendix A were also

checked against the wide range of energy audit information contained in the commercial building database developed by Engineering Interface Ltd.

The Marbek work also indicated that the only major shifts in energy end-use, conversion efficiencies and fuel shares that occurred between 1980 and 1985 are as follows:

- there was a general shift from oil to gas for heating in most subsectors;
- only office buildings showed any changes in tertiary end-use coefficients due to building envelope and lighting improvements in existing buildings and generally lower energy demands in new buildings.

A recent report by Marbek for Energy Mines and Resources Canada on the penetration of energy efficient fluorescent lighting in office buildings confirmed that this subsector is showing some improvement, with market shares for energy efficient units increasing from under 10% to about 20% between 1980 and 1985.

With some exceptions therefore, the potential for energy savings in the commercial/institutional sector remains untapped. The education, retail and warehouse subsectors consume large amounts of energy as do some of the smaller energy intensive subsectors such as restaurants. The impact of new buildings on energy use is currently quite small. The energy efficiency of new buildings is improving slowly.

It will be illustrated in Section 3, that by the Year 2000, an estimated 46% of buildings will have been built

since 1985. Therefore, there is a significant opportunity to ensure the energy efficiency of future building stock through initiatives.

TABLE 2.1

ESTIMATED FUEL USE IN ONTARIO
COMMERCIAL/INSTITUTIONAL SECTOR BY END-USE (1985)

Electricity	MWh	TJ
Heating[1]	2,550,373	9,181
Cooling[2]	3,032,627	10,915
Hot Water[3]	954,949	3,438
Lighting	10,843,164	39,035
Other[5]	938,207	3,377
Motors[4]	12,977,117	46,717
Total	**31,296,437**	**112,663**
Gas	1000 m^3	
Heating[1]	2,545,333	94,941
Hot Water[3]	277,255	10,342
Other[5]	187,967	7,011
Total	**3,010,554**	**112,294**
Oil	1000 L	
Heating[1]	396,630	15,203
Hot Water[3]	15,768	604
Total	**412,399**	**15,807**

Notes:

1 Heating includes electricity or fuel used for maintaining buildings at a set temperature but excludes electricity for air movement.

2 Cooling includes electricity used to operate compressors but excludes electricity used for air movement.

3 Hot water includes electricity or fuel used to heat water but excludes electricity used for pumping or circulation.

4 Motors includes all electricity used for pumping, circulation, or air movement for heating, cooling, hot water and ventilation.

5 Other includes electricity or fuel used for refrigeration, cooking and other specialized uses such as sterilization, etc.

Source: "Calibration of the Ministry of Energy Commercial Energy Demand Model". Prepared by Marbek Resource Consultants August, 1986 (Revised April, 1987).

TABLE 2.2

ESTIMATED FUEL USE IN ONTARIO
COMMERCIAL/INSTITUTIONAL SECTOR
BY SUBSECTOR (1985)

Subsector	Electricity (MWh)	(TJ)	Gas (1000 cu.m)	(TJ)	Oil (1000 L)	(TJ)
Schools	1,462,857	5,267	344,634	12,855	77,149	2,955
Universities/ Colleges	1,196,329	4,307	188,339	7,025	10,237	392
Health	1,628,913	5,864	227,315	8,479	11,132	426
Religious	372,609	1,341	142,248	5,306	44,195	1,693
Other Buildings[1]	1,940,357	6,985	153,900	5,740	17,500	670
Office	9,803,606	35,293	472,757	17,634	113,052	4,330
Food Retail	3,561,919	12,823	66,862	2,494	27,295	1,045
Other Retail	5,688,376	20,478	287,510	10,612	11,039	423
Hotels	1,195,131	4,302	97,422	3,634	8,344	320
Restaurants	2,018,201	7,266	327,239	12,206	13,260	508
Recreation	1,036,376	3,731	150,443	5,611	44,256	1,695
Warehouses	1,391,763	5,010	551,885	20,505	34,940	1,338
Total	**31,296,437**	**112,667**	**3,010,554**	**112,294**	**412,299**	**15,791**

Notes:

1 Other Buildings include transportation facilities (e.g. bus terminals, train stations, etc.), police stations, some types of nursing homes, etc.

Source: "Calibration of the Ministry of Energy Commercial Energy Demand Model". Prepared by Marbek Resource Consultants August, 1986 (Revised April, 1987)

2.2 Priority End-Uses

Any strategic energy conservation program must concentrate on those end-uses, fuels and subsectors that can provide the greatest savings. The following criteria were used to identify priority end-uses and fuels:

Fuel Demand:

- there should be increasing demand for the priority fuels with prospects that there will be a supply shortfall before 2000.

End-Uses:

- the priority end-uses should make up at least 10% of priority fuel use in the commercial/institutional sector.

Technical Potential:

- there should be the technical potential for significant savings in consumption and peak demand in each priority end-use and fuel in the form of commercially available technologies.

Market Potential:

- there should be the potential for significant penetration towards this technical potential in each priority end-use and fuel through market forces and government/-utility intervention as necessary.

Fuel Demand: The demand for oil, while not decreasing at such a rapid rate, is likely to continue to fall or level off in the future. Most oil users will choose to switch to gas or upgrade oil burners, etc. when existing equipment is due for replacement. Gas demand is increasing as more users switch from other fuels. Future

supplies are expected to be plentiful however, with the possible problem of system bottle necking during peak periods. Electricity demand is expected to increase with the overall size of the economy. New markets such as electrotechnologies and some losses to gas for more traditional end-uses will modify the growth rate. While there is currently a surplus of generation capacity in Ontario, there could be a supply shortfall before 2000. Electricity therefore will be considered as the only priority fuel.

End-Uses: Motors, lighting and cooling make up nearly 90% of all electricity demand in the commercial/institutional sector and each accounts for 10% or over. Motors and lighting are by far the largest end-uses representing 42% and 35% respectively. No other end-use accounts for more than 10% of electricity use.

Technical Potential: Commercially available technologies exist which can significantly improve the efficiency of electric motors, lighting and cooling in buildings, reducing both overall consumption and peak demand. There are also several technologies such as cogeneration and power factor correction which reduce electricity requirements across all end-uses.

Market Potential: While the speed at which more efficient technologies penetrate the commercial/institutional sector will ultimately depend on market forces and strategic intervention by governments and utilities, almost all subsectors use motors, lighting and cooling and the barriers to this penetration are not insurmountable.

In summary therefore, the priority fuels and end-uses addressed in this report are:

- Electric motors
- Lighting
- Cooling
- Cogeneration
- Power factor correction

2.3 Priority Technologies

Within the priority end-uses listed in Section 2.3, priority technologies were selected based on the following criteria:

- the size of the end-use in which the technology applies (the larger the end-use the more technologies were selected);

- the extent of the savings that might be realized with the technology;

- the commercial availability of the technology in Ontario or North America;

- the experience already gained in Ontario and North America with the technology.

The selected technologies are shown in Table 2.3.

TABLE 2.3

PRIORITY COMMERCIAL/INSTITUTIONAL TECHNOLOGIES

End-Use	Technology
Cooling	High Efficiency Mechanical Cooling
	Energy Efficient Unitary Air Conditioning Equipment
Lighting	Low Wattage Par Lamps
	Screw-in Fluorescent Lamps
	Energy Efficient Fluorescent Lamps
	Energy Efficient Ballasts
	High Efficiency Luminaires
	Light Switching
	Light Automation
	Occupancy Lighting Controls
	Daylighting
Electric Motors	Energy Efficient Motors
	Variable Speed Drives
	Energy Management Controls
	Air Balancing
	Water Balancing
Total Electricity	Cogeneration
	Power Factor Correction

3.0 THE POTENTIAL FOR ENERGY MANAGEMENT

3.1 Existing Buildings

The potential for energy use reduction in existing buildings relates to the aggregate technical potential of various energy management measures, and the extent to which that potential has already been exploited.

The rapid increase in energy costs in the early 1970's resulted in a flood of activity and interest in energy conservation, from about 1975 to 1983. Increasing energy bills provided a strong incentive to proceed with energy management on a project by project basis.

Energy management projects compared favourably with competing applications of financial resources. Therefore, selected projects would proceed based on economic criteria.

As the cost of energy stabilized, the perceived financial return for energy management projects declined. Energy conservation projects would receive a lower priority compared to competing projects.

The economic decision criteria, and project by project evaluation of energy conservation activities produced a marked reduction in energy conservation activity from 1984 to 1987.

As an alternative to the project approach to energy use reduction, energy management can be viewed as an ongoing process that is integrated with routine building operation and maintenance. The process approach to energy management involves analysis and monitoring in addition to energy conservation measures.

Monitoring energy savings provides feedback to the process, to ensure that projected savings are achieved and maintained.

The commercial and institutional building owners and managers have not embraced the process approach to energy management. Many building owners and managers have experienced significant problems with energy conservation measures. The problems with new technology and implementation have reduced the appeal of energy conservation. As a result, there is still substantial energy reduction potential to be exploited. With stable and decreasing energy bills, only a small proportion of this potential will be realized, without external input.

Overcoming the barriers to the process approach to energy management will require improved energy management awareness, and increased expertise in managing the energy management process.

Specific technology transfer will also be necessary, to reduce the risk perception associated with energy reduction strategies.

Different approaches will be required in the different building subsectors. Variation in building characteristics within subsectors will also influence the approach which should be taken. For example, new buildings will require different incentives from existing building stock. The special considerations for new buildings will be discussed in Section 3.2.

In existing buildings, there are several factors which influence the opportunities available, and the type of incentives which should be used.

Building size is a convenient indicator which encompasses many of these factors. The estimated total floor area, number of buildings and average floor area in each subsector are presented in Table 3.1. Table 3.2 provides definitions of the types of buildings included in each subsector.

Estimated frequency distributions by floor area are shown in Figures 3.1 (a) through (l), for each building subsector.

From the frequency distributions, each subsector has been segmented into small and large buildings. The small vs large segmentation indicates the size of the building groups within each subsector, which will require different approaches to promoting energy management. For example, small retail stores have highly fragmented ownership, implying a larger effort per MWh saved for this group than for large stores.

There are also economies associated with building size which will have an impact on the adoption of technologies by building owners. For example, installation of an energy management control system in an office building entails a substantial fixed cost component for design, tendering and central computer equipment. Therefore, the average cost per square foot of building floor area will be lower in a large building than in a small building.

The most accessible buildings for energy management incentives will be large buildings and small buildings with common ownership, (such as chains of retail stores). These segments contain the buildings where the greatest penetration of technology has already occurred.

The division point for small vs large buildings is based on the shape of the distribution, the average building size, the resulting number of buildings, and floor area in each segment.

The frequency distributions were based on several sources and constitute a preliminary assessment of the distribution of buildings by floor space. Table 3.3 outlines the information sources on which the distribution for each subsector is based. In all cases, the total floor area in the subsector is based on the estimates shown in Appendix A.

Time constraints tend to limit the number of design options considered, as engineers are pushed to produce designs quickly.

Most designers have revised their designs to address the higher cost of energy in the 1980's. Systems are now designed to avoid simultaneous space heating and cooling. Lighting and motor loads have also been reduced. Many of these design changes are the result of voluntary guidelines published by such groups as the American Society for Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) and the Illuminating Engineering Society.

Ontario has no legislated design standards for energy efficient design of new buildings. Considerable experience has been accumulated in this area in the State of California. "Title 24" legislation, in California has set relatively loose standards for energy efficient design of new buildings. Incentives are then provided for designs which "beat" the standard. The lenient standards are easy for most builders and manufacturers to live with, and provide room for increased stringency if energy prices increase. Some California utilities provide an incentive of $300 per kW avoided for commercial/industrial users.

Two important lessons have been drawn from the California experience. The first is the importance of tying the incentive to the amount of energy saved, not to the first cost of implementing the energy saving technology. This practice encourages owners and designers to select the energy saving options with the greatest savings potential.

The second lesson learned is the importance of monitoring the energy performance of new buildings with "low energy" designs, to ensure that the energy reduction has actually been achieved. California has realized that allocating funds for the provision of energy monitoring facilities is as valuable as the funds allocated to incentives.

Energy conserving options selected at the design stage are far less costly than energy retrofits to existing buildings. By setting low energy design standards and providing incentives to reduce energy use, California has motivated new building owners to conserve energy at

the design stage. California utilities have avoided construction of an estimated 7 generating plants by investing approximately 3% of revenue for incentive programs.[1]

For example, the premium cost of energy efficient motors for fans (about 25%) is negligible in comparison to total construction costs and is readily paid back in energy savings, over the motor's life. In an existing building, application of this technology requires replacement of an existing motor. Replacement is only economic for motors which must be replaced due to breakdown.

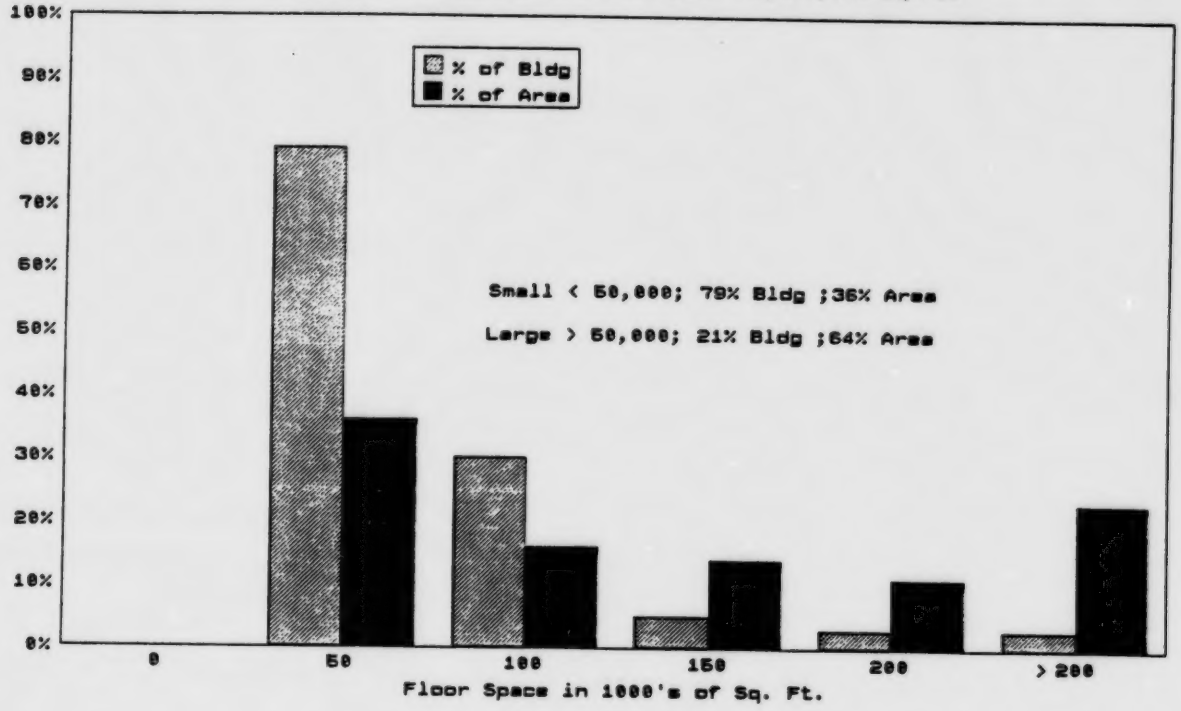
Another example is the installation of an energy management control system. Installation during construction is much less expensive because of the lower cost of running wire. Costs for modification of existing analog controls to be compatible with an automated control system, can also be avoided.

The California experience has illustrated that the application of technologies such as energy efficient motors and energy management control systems, can be accelerated by legislated design standards and/or energy conservation incentives. Capital investment in generating capacity can be avoided in Ontario by instituting low energy design codes and providing incentives.

[1] **Source:** Dr.A.Rosenfeld's presentation to the Ontario Select Committee on Energy, 1985

FIGURE 3.1

(a) SCHOOLS
Total Buildings 4126; Total Area 178,493,000 Sq.Ft.



(b) COLLEGE / UNIVERSITY
Total Buildings 77; Total Area 71,055,000 Sq.Ft.

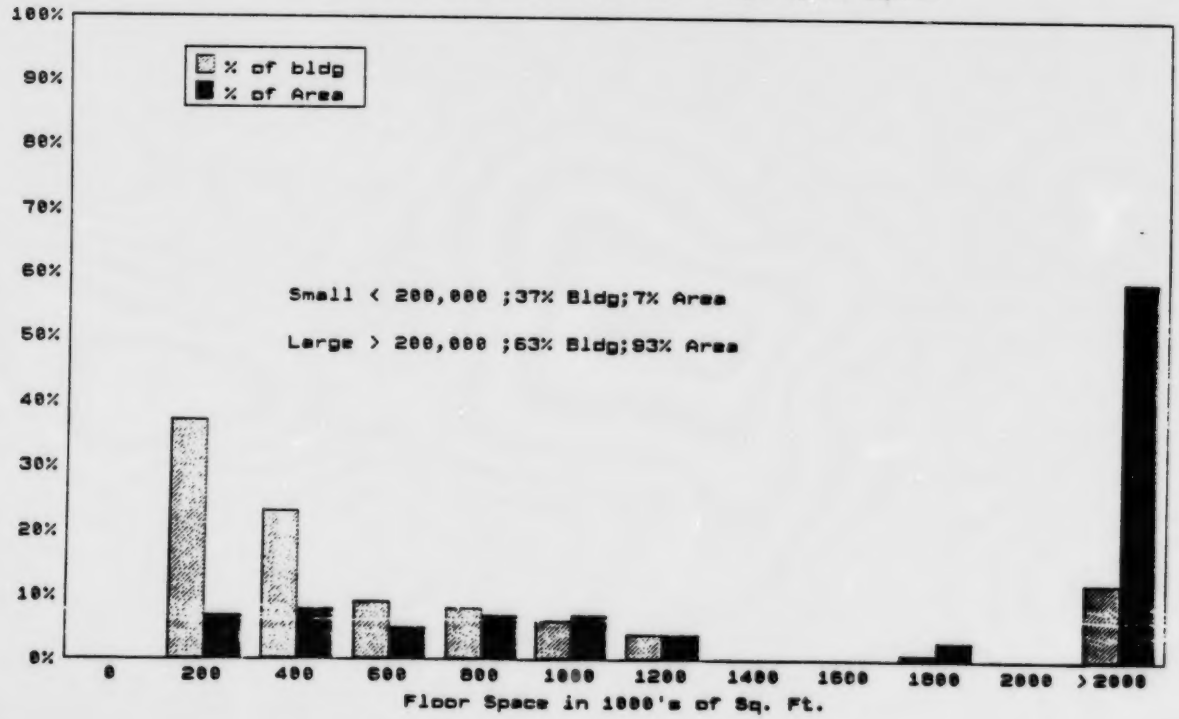
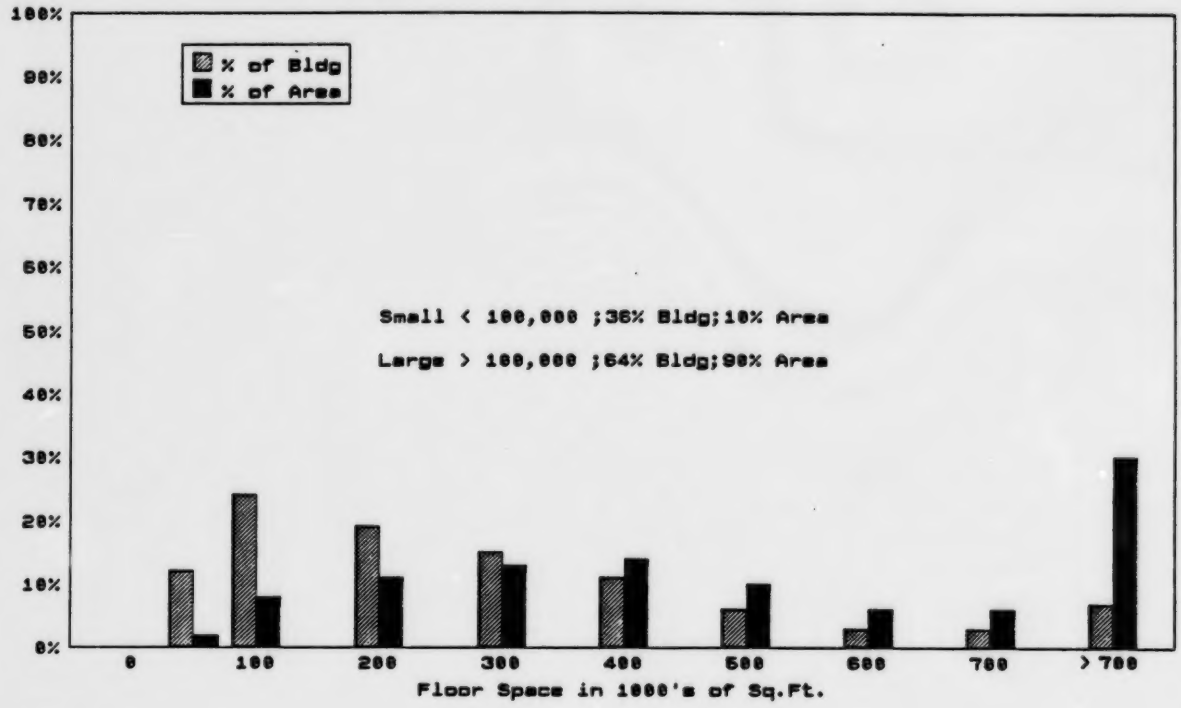


FIGURE 3.1 (cont'd)

(c) HEALTH
Total Buildings 236; Total Area 74,842,000 Sq.Ft.



(d) RELIGIOUS
Total Buildings 5340; Total Area 42,781,000 Sq.Ft.

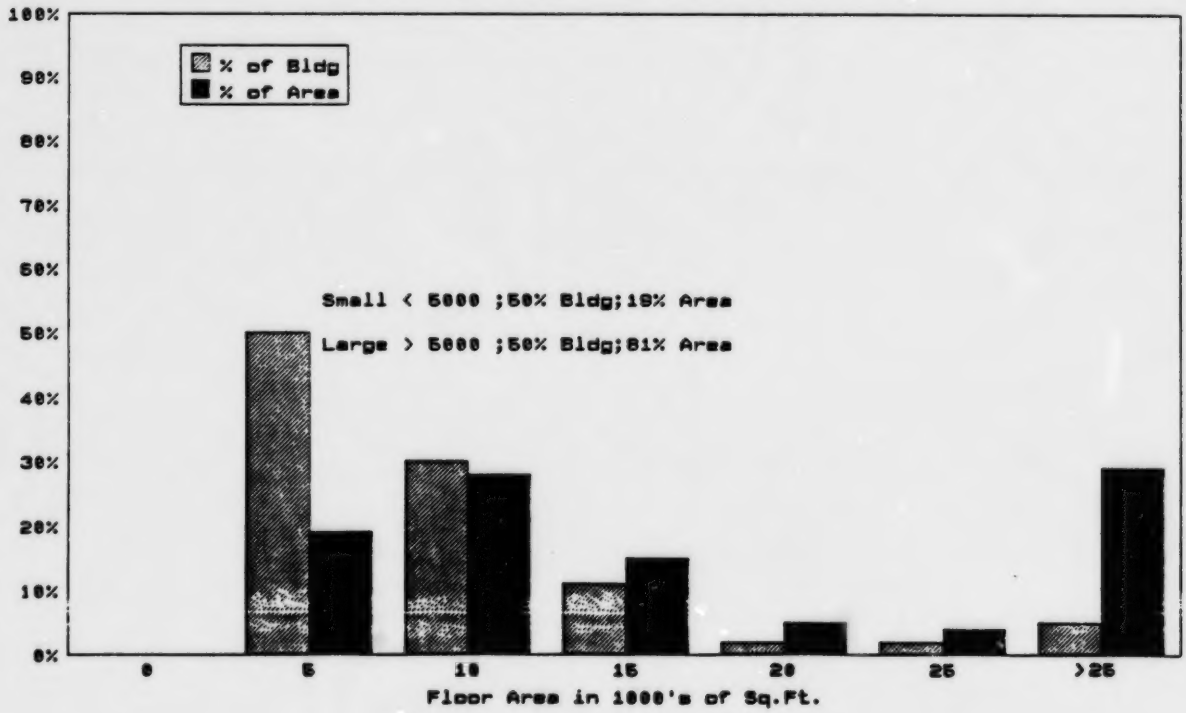
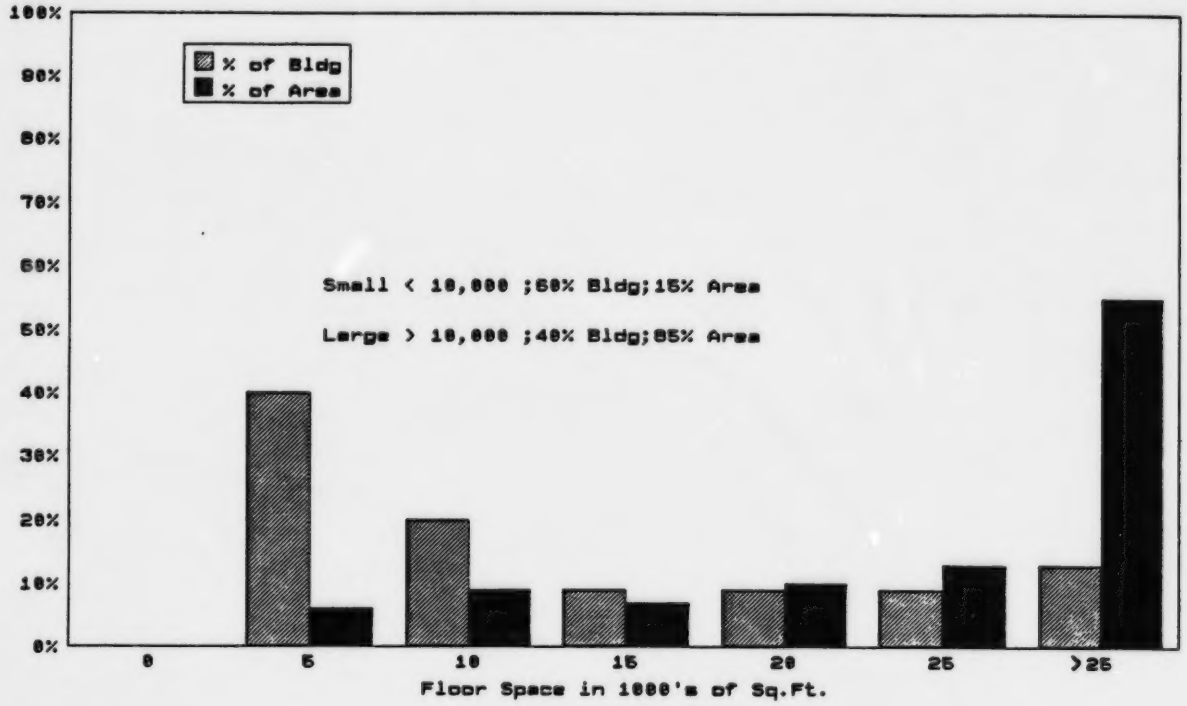


FIGURE 3.1 (cont'd)

(e) OTHER
Total Buildings 3220; Total Area 51,475,000 Sq.Ft.



(f) OFFICE
Total Buildings 27,530; Total Area 404,629,000 Sq.Ft.

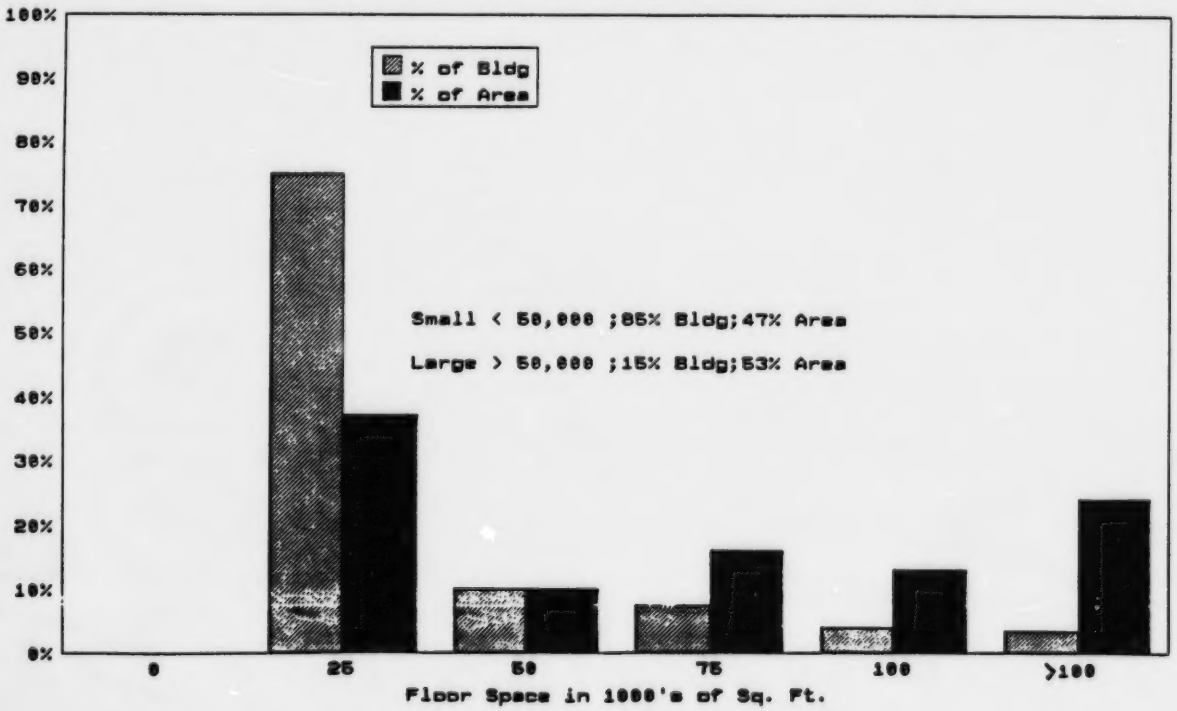
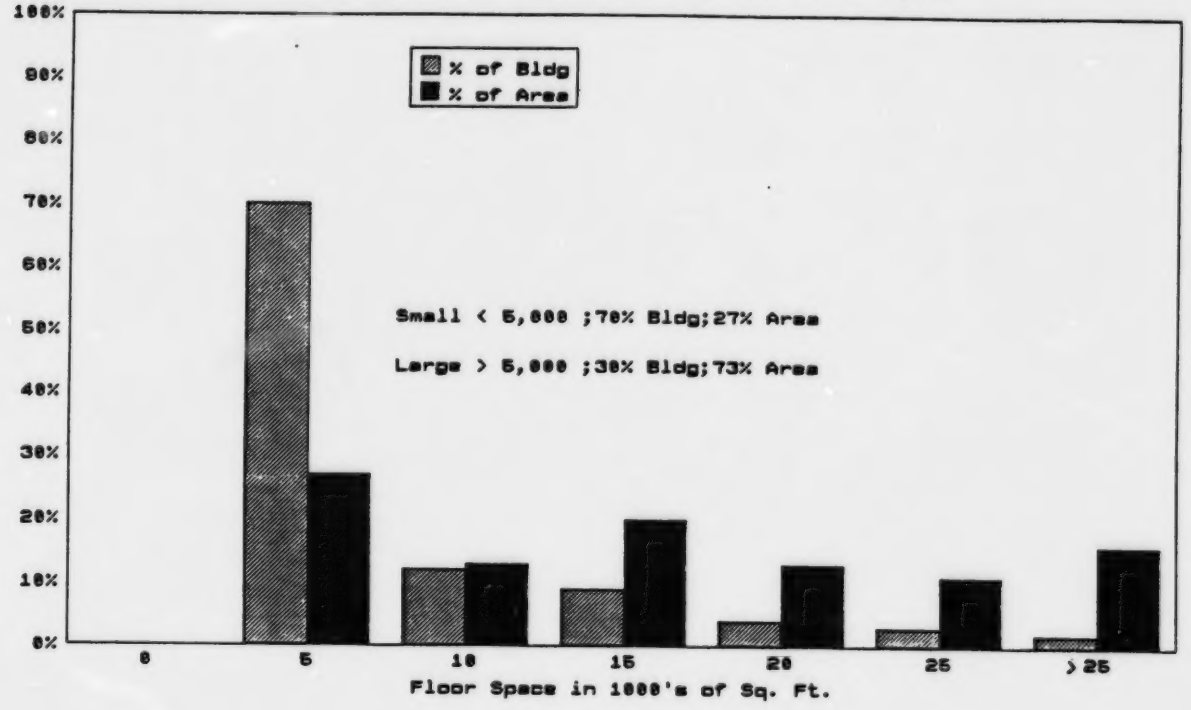


FIGURE 3.1 (cont'd)

(g) RETAIL FOOD
Total Buildings 9200; Total Area 49,795,000 Sq.Ft.



(h) OTHER RETAIL
Total Buildings 19,860 ; Total Area 192,620,000 Sq.Ft.

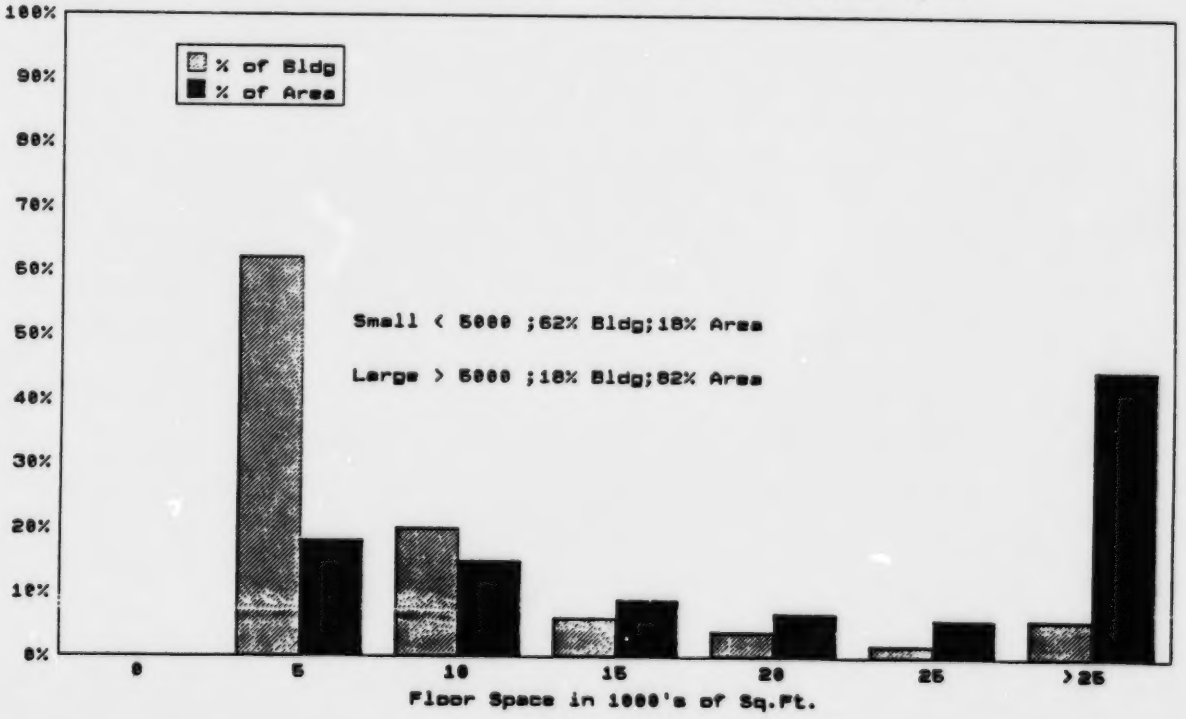
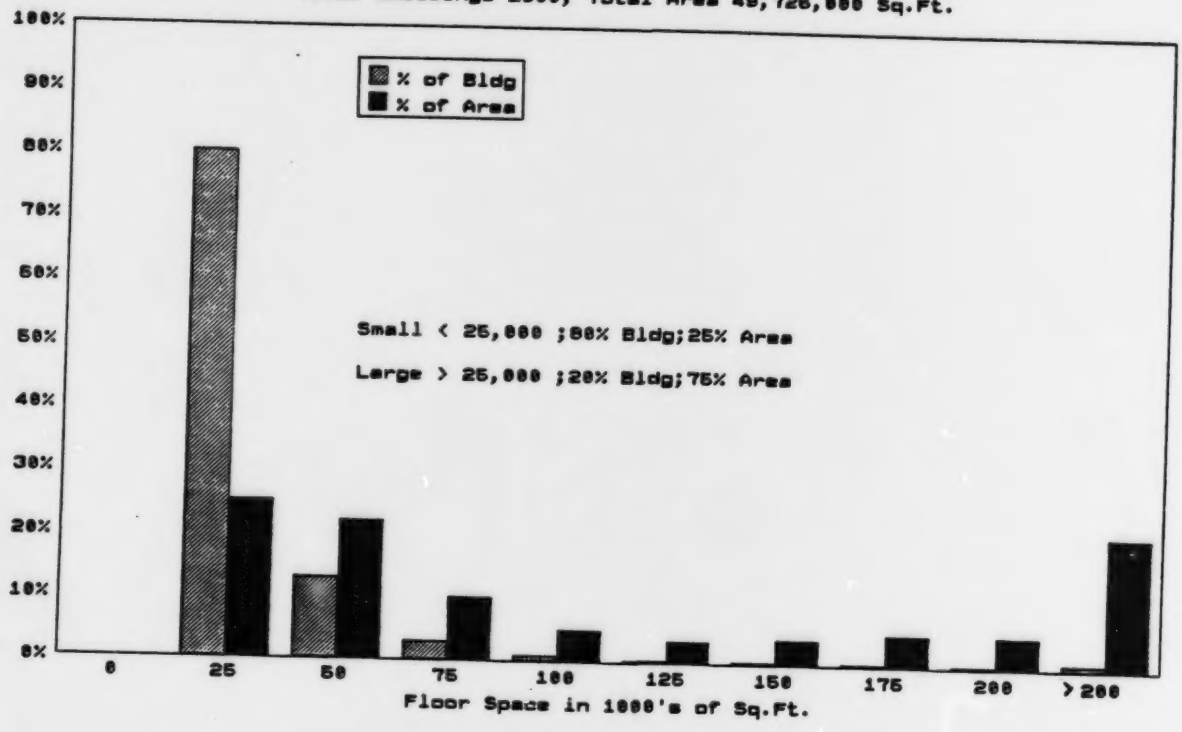


FIGURE 3.1 (cont'd)

(i) HOTEL/MOTEL
Total Buildings 2900; Total Area 49,726,000 Sq.Ft.



(j) RESTAURANTS
Total Buildings 11,330; Total ARea 61,173,000 Sq.Ft.

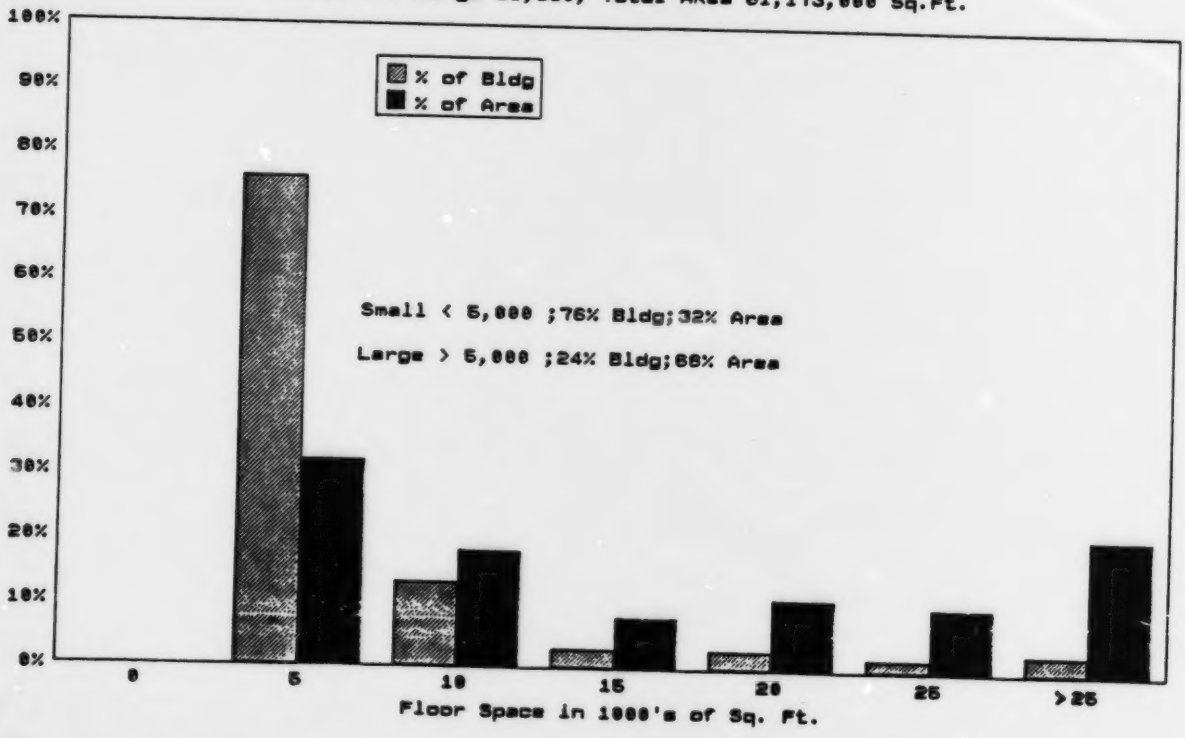
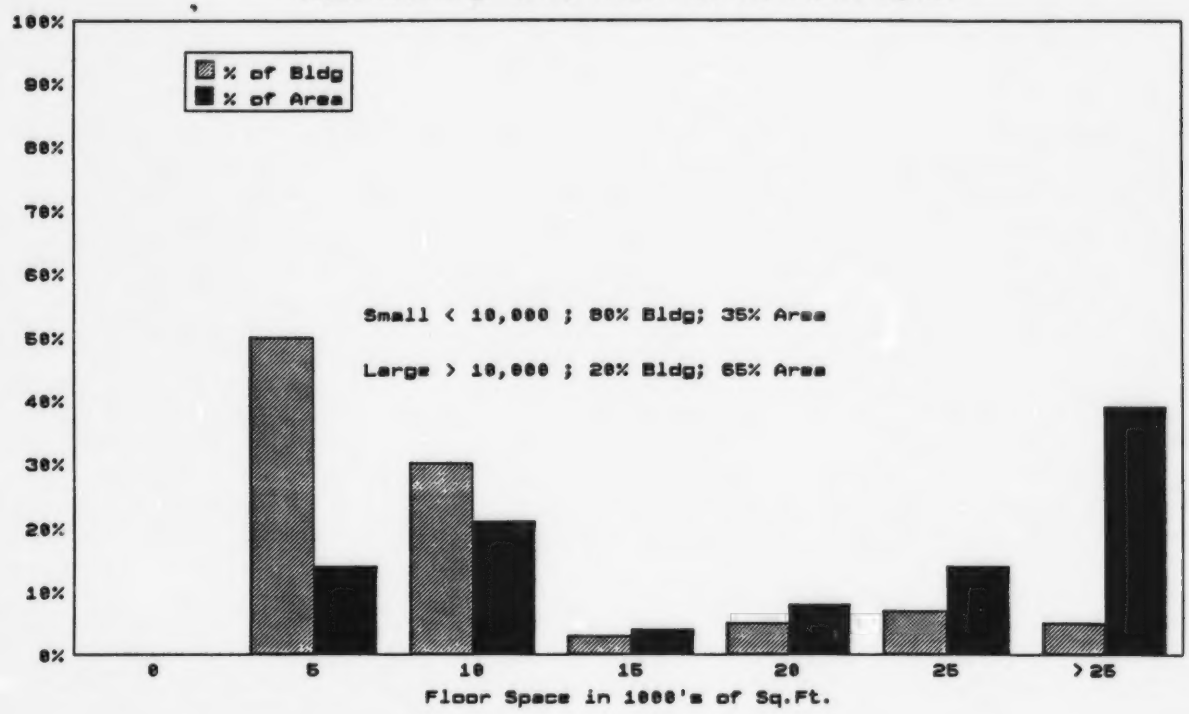


FIGURE 3.1 (cont'd)

(k) RECREATION
Total buildings 3870; Total Area 46,404,700 Sq.Ft.



(l) WAREHOUSE
Total Buildings 15,000; Total Area 240,100,000 Sq.Ft.

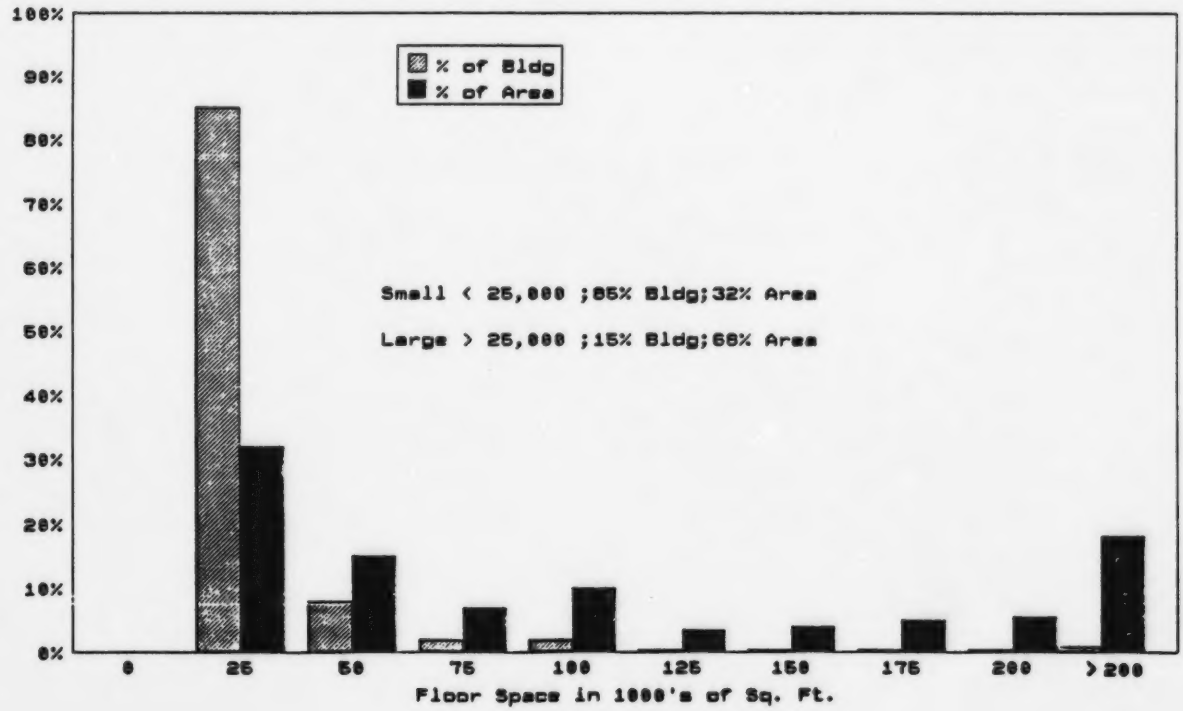


Table 3.1

Estimated Number of Buildings and Total Floor Area for each Subsector

Subsector		Number of Buildings	Total Floor Area (000's sq.ft.)	Average Floor Area (sq.ft.)
1.	Schools	4,126	178,493.0	43,260
2.	Universities & Colleges[1]	77	71,055.0	934,900
3.	Health[2]	236	74,842.0	317,000
4.	Religious Buildings	5,340	42,701.8	8,000
5.	Other Buildings	3,220	51,475.8	16,000
6.	Office Buildings	16,000	404,629.0	25,000
7.	Food Retail Stores	9,200	49,795.5	5,400
8.	Other Retail Stores	19,860	192,620.0	9,700
9.	Hotels & Motels	2,900	49,726.0	18,000
10.	Restaurants	11,330	61,173.3	5,400
11.	Recreation	3,870	46,404.7	12,000
12.	Warehouses	15,000	240,100.0	16,000

Notes: [1] Floor area is per institution, not per building

[2] See Table 3.2 for classification of subsector buildings.

Table 3.2

Building Types Included in Subsectors

Subsector	Buildings Included in Subsector
1. Schools	• Public and Separate Elementary and Secondary Schools
2. Universities & Colleges	• Universities, Community and Vocational Colleges
3. Health	• Hospitals
4. Religious	• Religious assembly buildings of all documented denominations
5. Other	• Special health care facilities including nursing homes, transportation terminals and garages, correctional institutes, police stations, etc.
6. Office	• Office buildings of all sizes
7. Food Retail	• Chain and independent stores with primary revenue from food sales
8. Other Retail	• Chain and independent stores with primary revenue from non-food sales
9. Hotels and Motels	• Hotels, motels, lodges and inns including those with seasonal operation
10. Restaurants	• Establishments with table service, fast food outlets and coffee shops
11. Recreation	• Arenas, gymnasia, pools, indoor racquet courts, etc., not included in other subsectors
12. Warehouses	• All warehouse floor space not included in other subsectors

Table 3.3

Information Sources for Building Frequency Distributions

Subsector	Sources	Comments
1. Schools	• Ontario Ministry of Education[1] areas of all schools by board	•shape of distribution can be refined
	• US frequency distributions[2] schools	
2. Universities & Colleges	• Ontario Ministry of Colleges[3] and Universities	
3. Health	• Ontario Ministry of Health[4] number of beds for all hospitals. Area estimated by average sq.ft./bed	
	• EIL database information	
4. Religious	• US frequency distribution for "assembly" buildings	• further refinement needed on number of buildings, average size, and shape of distribution
5. Other	• US frequency distribution for "assembly" buildings	• further refinement needed on number of buildings, average size, and shape of distribution
6. Office	• US frequency distribution for "office" buildings	• further refinement needed on number of buildings, average size, and shape of distribution
	• EIL database information	

Table 3.3

Information Sources for Building Frequency Distributions

Subsector	Sources	Comments
7. Food Retail	• US frequency distribution for "Food Sales & Service"	• further refinement needed on number of buildings, average size, and shape of distribution
8. Other Retail	• US frequency distribution for "Food Sales & Service" • EIL database information	• further refinement needed on number of buildings, average size, and shape of distribution
9. Hotels/Motels	• EMR data on area and number of rooms (1976)[5]	• shape of distribution can be refined
10. Restaurants	• US frequency distribution for "Food Sales & Service"	• further refinement needed on number of buildings, average size and shape of distribution
11. Recreation	• US frequency distribution for "assembly" buildings	• further refinement needed on number of buildings, average size and shape of distribution
12. Warehouses	• US frequency distribution for "Warehouses"	• further refinement needed on number of buildings, average size and shape of distribution.

Notes: 1 Energy Consumption Analysis of Schools, Ontario Ministry of Education, October 1985

2 Characteristics of Commercial Buildings 1983, US Department of Energy, July 1985

3 Report on Energy Consumption and Acquisition Cost, Ministry of Colleges & Universities, December 1985

4 Hospital Statistics, 1983/84, Ontario Ministry of Health, Information & Systems Division

5 Hotels and Motels: Energy Consumption & Potential Savings, EMR, 1983

3.2. New Buildings

Figure 3.2 shows that in the year 2000, approximately 46% of floor space will have been built since 1985. The high proportion of new buildings in total building stock emphasizes the importance of energy management initiatives in the design of new buildings.

Ensuring reduced energy consumption of "new" building stock in 2000 requires adoption of energy management technologies into the buildings being designed now. It is more cost effective to incorporate low energy technology in buildings during the design stage than to retrofit the buildings after they have been constructed.

The projections of remaining and "new" buildings in the year 2000 are based on the projected rate of construction to replace demolished buildings, and the rate of incremental construction. The rates used were provided by Ontario Hydro and are incorporated in Figure 3.3

Figure 3.3 reflects an average compounded building replacement rate of approximately 1.5% per year from 1986 to 2000. Increased detail in projecting construction and demolition rates would provide greater accuracy in estimating the magnitude of savings potential and initiatives necessary to promote energy efficient design of new buildings, in each subsector.

The design of new commercial buildings involves selection among possible design alternatives for building systems. Several factors influence the selection. Budgetary constraints generally receive the greatest emphasis. As a result, design decisions tend to be highly capital cost oriented and typically not approached from a life cycle cost viewpoint.

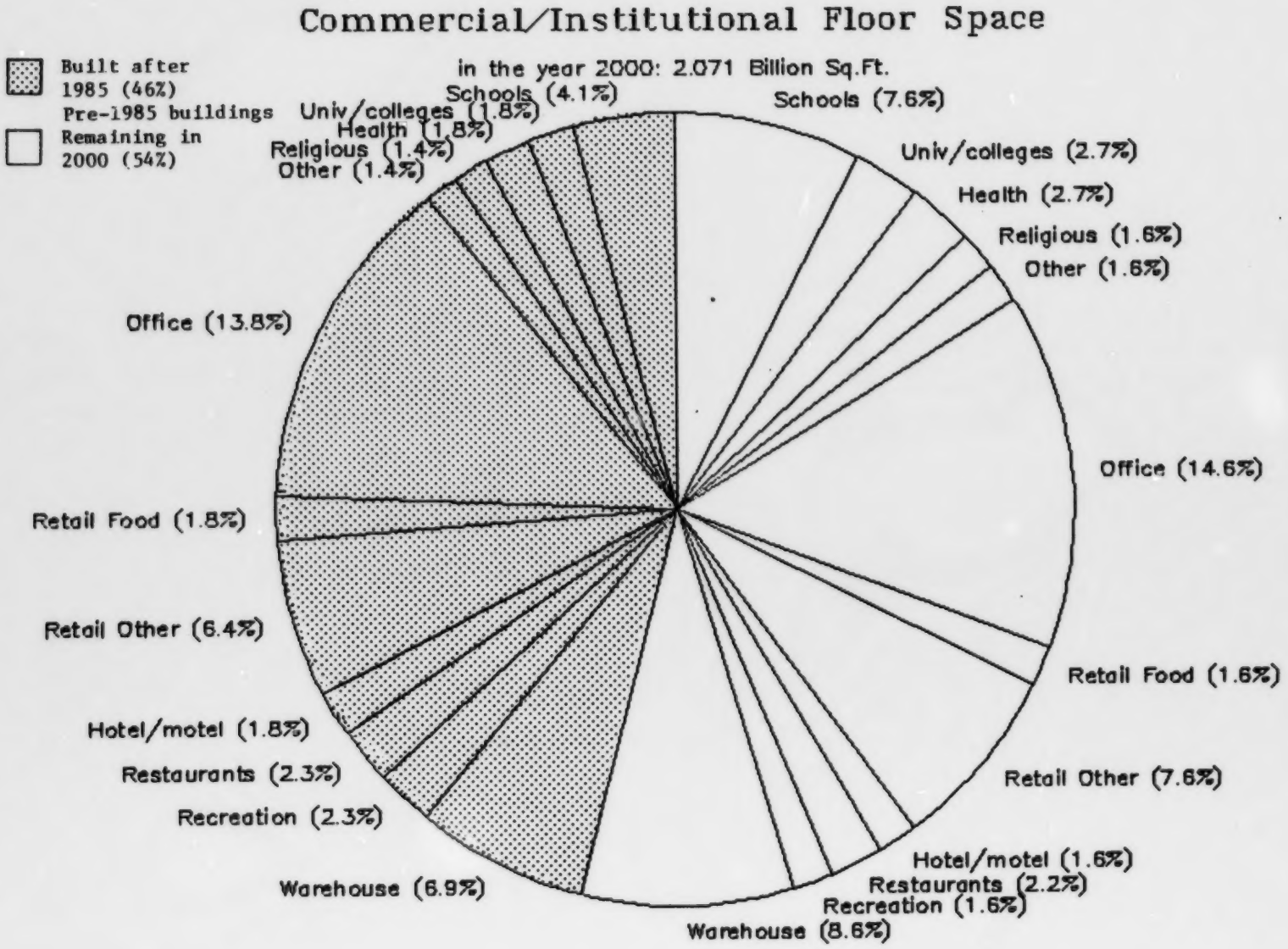

Commercial/Institutional Floor Space
in the year 2000: 2.071 Billion Sq.Ft.
Built after 1985 (46%)
Pre-1985 buildings Remaining in 2000 (54%)
Schools (4.1%)
Univ/colleges (1.8%)
Health (1.8%)
Religious (1.4%)
Other (1.4%)
Office (13.8%)
Retail Food (1.8%)
Retail Other (6.4%)
Hotel/motel (1.8%)
Restaurants (2.3%)
Recreation (2.3%)
Warehouse (6.9%)
Schools (7.6%)
Univ/colleges (2.7%)
Health (2.7%)
Religious (1.6%)
Other (1.6%)
Office (14.6%)
Retail Food (1.6%)
Retail Other (7.6%)
Hotel/motel (1.6%)
Restaurants (2.2%)
Recreation (1.6%)
Warehouse (8.6%)

FIGURE 3.2

FIGURE 3.3

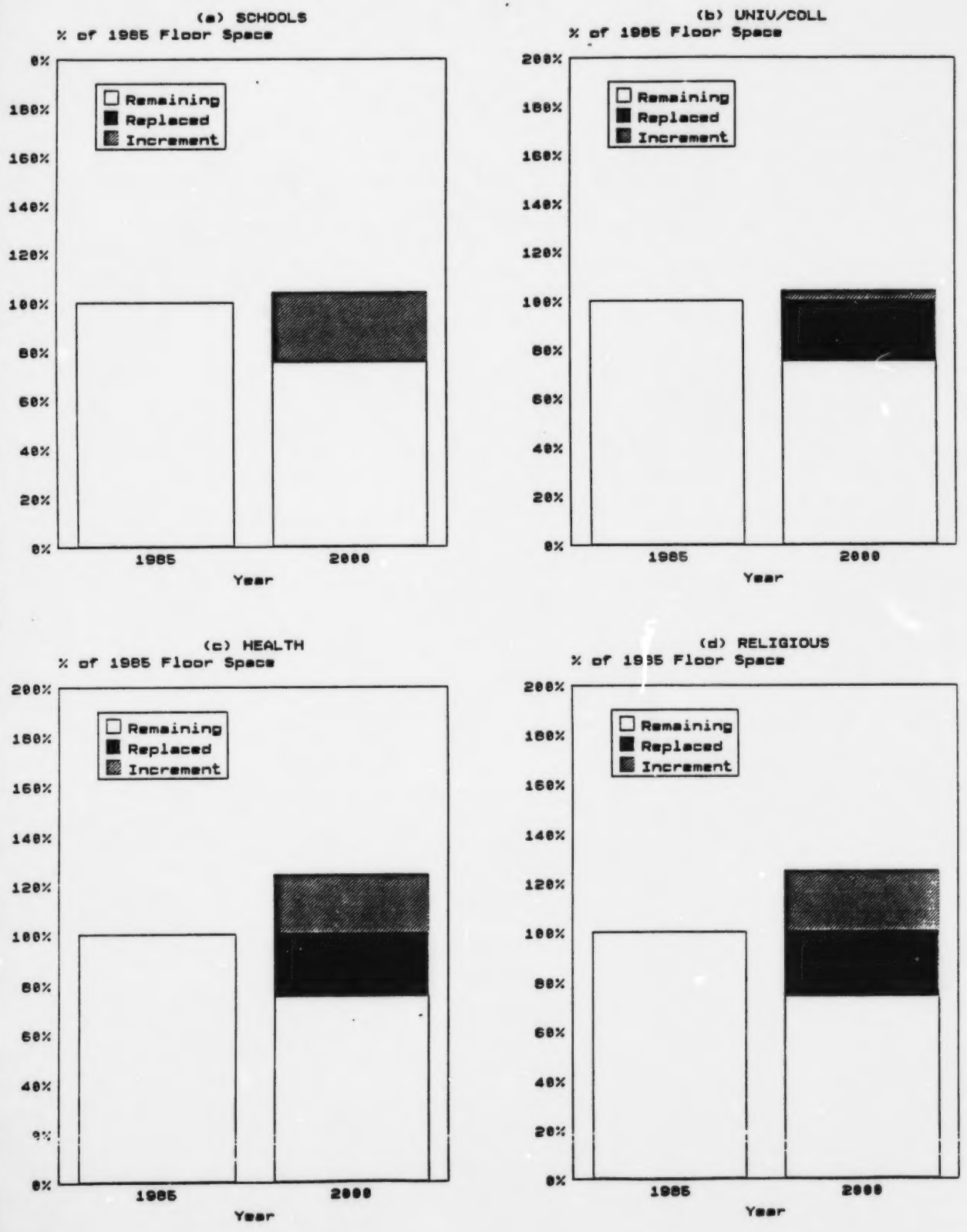
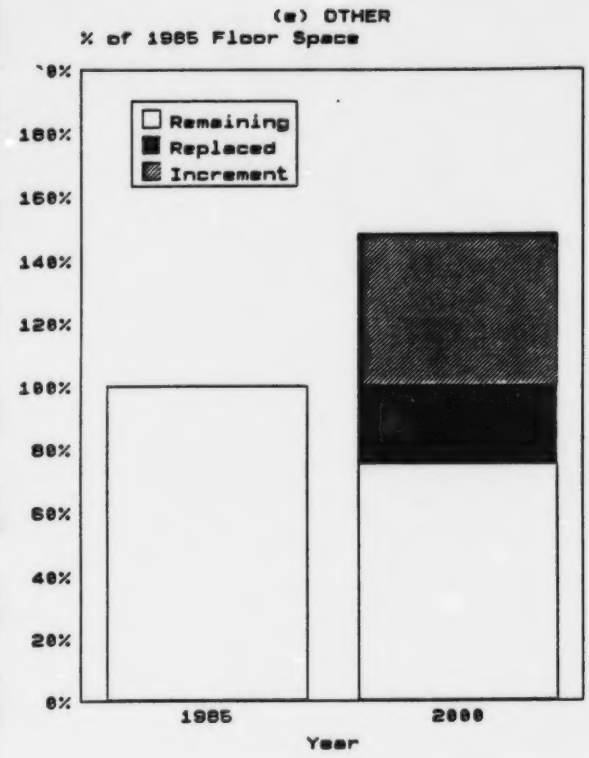
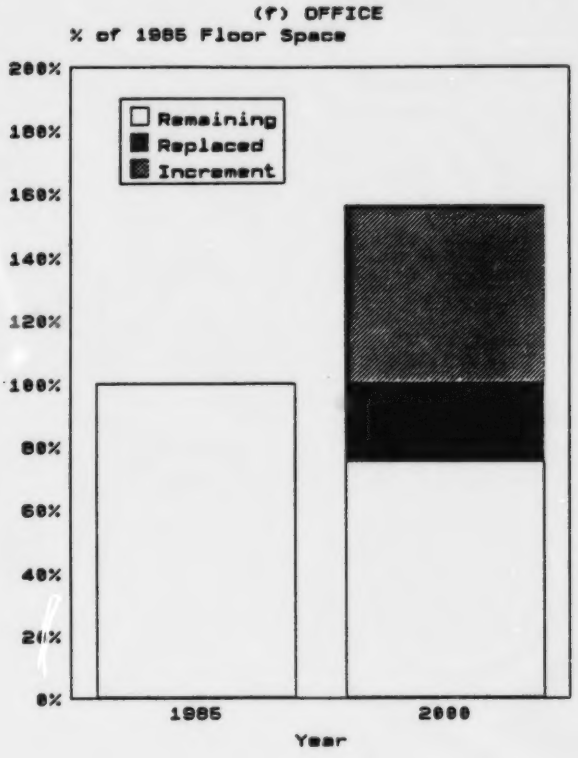
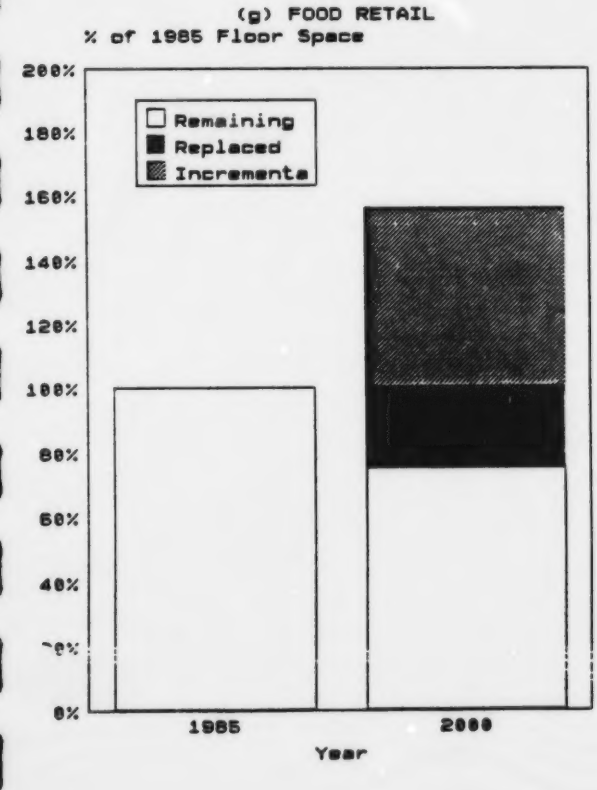

(a) SCHOOLS
% of 1985 Floor Space
Remaining
Replaced
Increment
200%
180%
160%
140%
120%
100%
80%
60%
40%
20%
0%
1985
2000
Year
(b) UNIV/COLL
% of 1985 Floor Space
Remaining
Replaced
Increment
200%
180%
160%
140%
120%
100%
80%
60%
40%
20%
0%
1985
2000
Year
(c) HEALTH
% of 1985 Floor Space
Remaining
Replaced
Increment
200%
180%
160%
140%
120%
100%
80%
60%
40%
0%
1985
2000
Year
(d) RELIGIOUS
% of 1985 Floor Space
Remaining
Replaced
Increment
200%
180%
160%
140%
120%
100%
80%
60%
40%
20%
0%
1985
2000
Year

FIGURE 3.3 (cont'd)







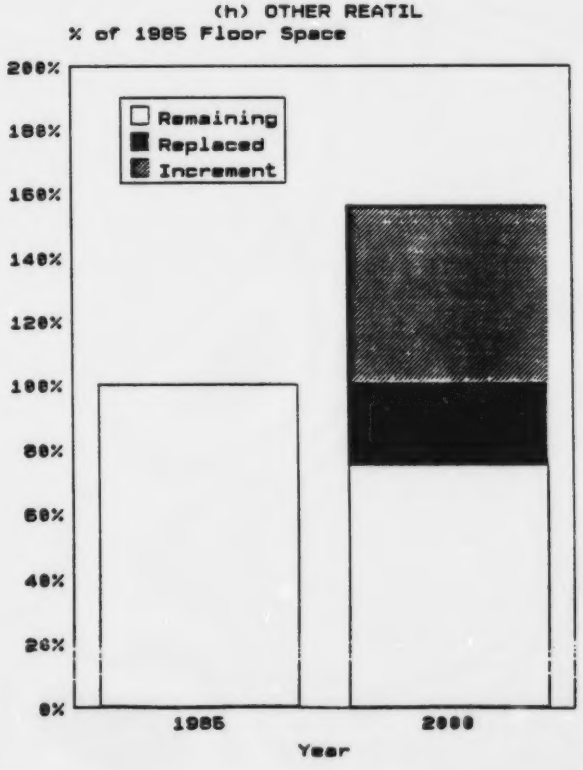
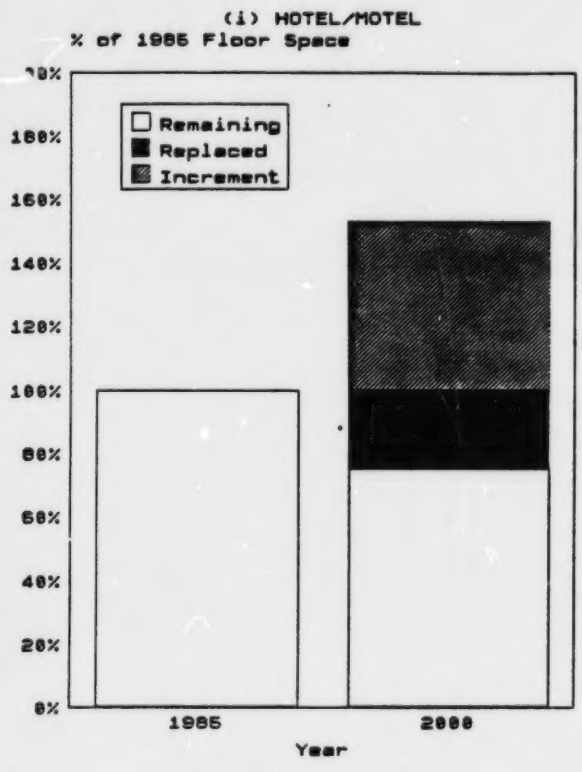
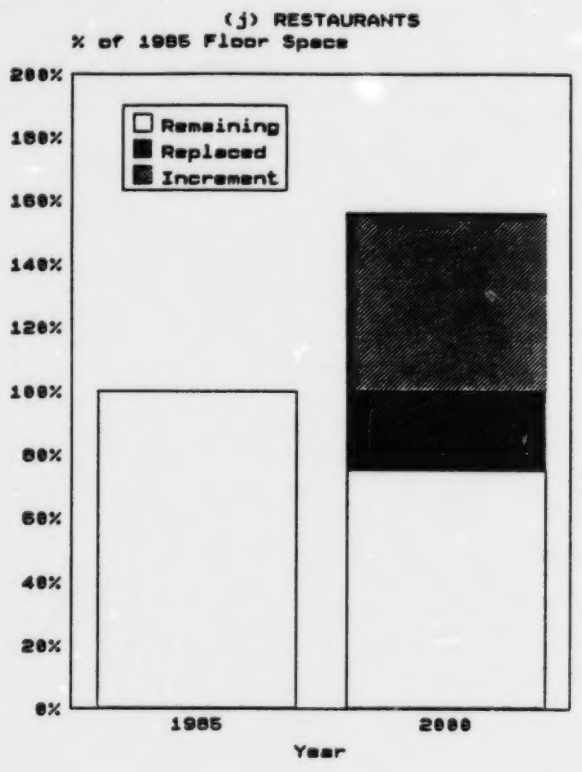
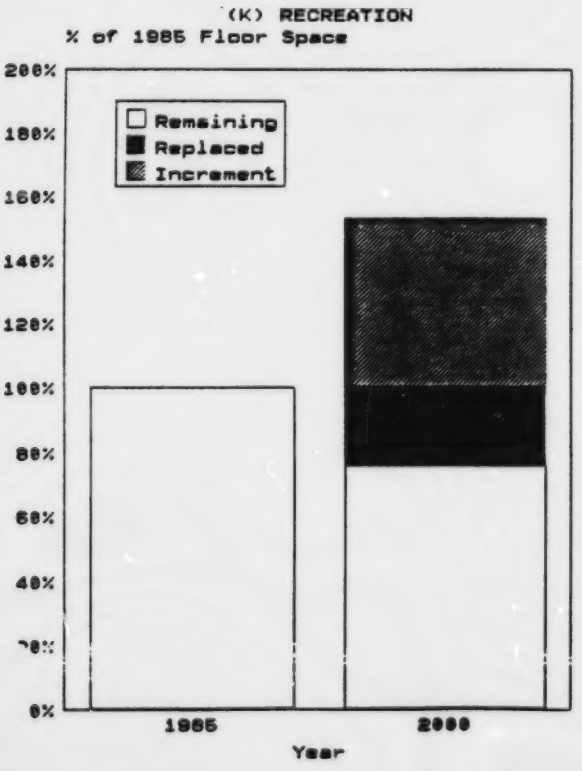
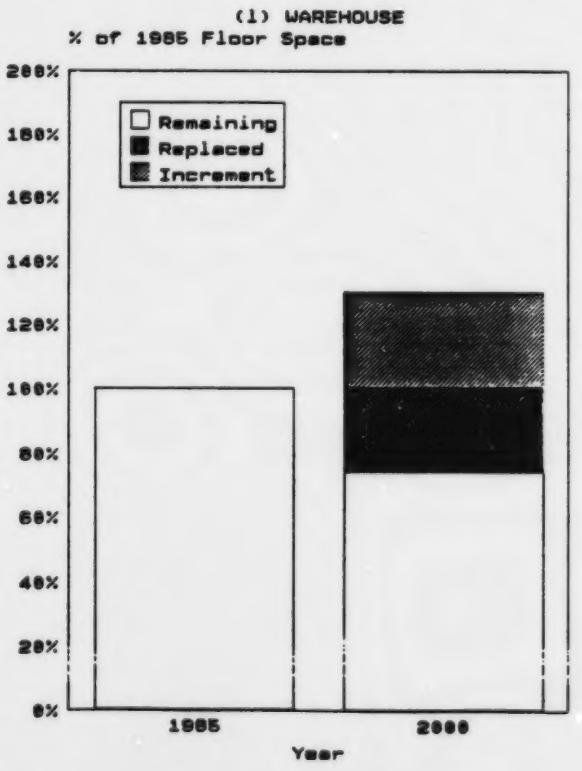


FIGURE 3.3 (cont'd)









4.0 TECHNOLOGY REVIEW AND PROFILES

4.1 Introduction

As discussed in Section 2 the technology profiles presented in this report relate only to electrical end-use. They are grouped according to the following end-use categories:

1. Cooling
2. Lighting
3. Motors
4. Total Electrical Energy Use

The Energy Reducing Measures included in the database are shown in Table 4.1, together with the total energy savings potential expressed as a percentage of electrical energy end use.

The eighteen measures selected do not represent all potential electrical energy savings. An attempt was made in this report to concentrate

For many of the measures selected, there will be an energy impact on other end-uses. For example, reduction in lighting load reduces the heat from lights which must be removed by a building's air conditioning system. Therefore, a measure such as replacing conventional luminaires with fewer, more efficient luminaires, affects the cooling energy end-use, as well as the lighting energy end-use. Similarly, the heating energy use may increase with a decrease in lighting energy use.

The energy management measures which involve more than one end-use category are shown in Table 4.2. Quantification of this overlap requires dynamic simulation of building energy use, since each building will have different characteristics. The Energy Technology Database does not incorporate factors to quantify this overlap but could be modified to do so.

Table 4.1

Measures included in Database

and their Associated Electrical Energy Savings Potential

Cooling/Refrigeration End-Use	% Energy Savings Potential (ESP)	
High Efficiency Central Cooling	18	
High Efficiency Unitary Cooling	12	
Lighting End-Use		
Low Wattage Par Lamps	45	
Screw-in Fluorescent Lamps	70	
Energy Efficient Fluorescent Lamps	10	
Energy Efficient Ballasts	10	
High Efficiency Luminaires	35	
Light Switching	15	
Lighting Automation	20	
Occupancy Lighting Controls	35	
Daylighting	50	
Motors End-Use		
Energy Efficient Motors	7	
Variable Speed Drives	60	
Energy Management Control Systems	20	
Air Balancing	25	
Water Balancing	15	
Total Energy End-Use		
Power Factor Correction	0	(5% saving on demand)
Cogeneration	50	

Table 4.2

Effect of Energy Management Measures on

Other End-Use Categories

Measure	End-Use Category	Impact on Other Energy End-Use
Low Wattage PAR Lamps	Lighting	Reduces building cooling use, may increase heating energy use
High Efficacy Fluor.	Lighting	Reduces building cooling use, may increase heating energy use
High Efficiency Luminaires	Lighting	Reduces building cooling use, may increase heating energy use
Light Switching	Lighting	Reduces building cooling use, may increase heating energy use
Lighting Automation	Lighting	Reduces building cooling use, may increase heating energy use
Daylighting	Lighting	May reduce heating energy use and affect cooling use
Energy Efficient Motors	Motors	May reduce cooling use
Variable Speed Drives	Motors	Reduces energy required to heat and cool air
Air Balancing	Motors	Reduces energy required to heat and cool air
Water Balancing	Motors	Reduces energy required to heat and cool air

Further information on each energy management measure is presented in the Technology Profiles. The profiles include the following sections:

General Description

- outlines the measure, the technology involved and how it is implemented (including schematic drawing).

Specifications

- outlines key points for effective implementation of the measure

Field Experience

- commentary on existing applications of technology, adoption to date, and barriers to adoption.

Energy Savings

- outline of how savings are achieved, average technical savings potential across sector, impact on other energy end uses, other benefits of measure.

Payback Period

- an estimate of the capital cost premium for measure
- the typical simple payback range for the measure

Applicability

- matrix of applicability factors (A) from database
- qualitative aspects of applicability.

Barriers

- the economic, informational and other barriers preventing widespread implementation of the measure.

Penetration

- current market penetration of the technology
- prospects for future market penetration and the policies/programs which might accelerate penetration

Overall Impact

- the potential energy savings in Ontario that might be expected as a result of increased application of the measure

Comments

- miscellaneous notes on the measure or technology and its use in Ontario

4.2 Energy Technology Database

A database was developed to record and quantify the potential energy reduction from specific energy management measures, for use in the technology profiles. The database is constructed such that the potential energy savings for any or all building subsectors can be quantified for any or all of the measures selected.

The energy management measures are organized by energy end-use. End-use is defined according to building subsector and fuel type (electricity, gas or oil). Together, these characteristics determine the potential

energy reduction for each measure.

For each measure there are attributes such as description, application and barriers, as well as the energy use data necessary for computing the potential energy savings. The database also contains three fields containing the factors used to scale the per unit energy savings potential.

The first factor relates to the measure's impact on its end-use (i.e., the measure's technical potential). This is the energy savings factor shown in Table 4.1. The second factor relates to the measure's impact in a particular category of building sector, (i.e., the fraction of energy use to which the measure applies). The third factor relates to the actual current or future market penetration of the technology. The net result is a number which represents the potential reduction in energy use for implementation of a particular measure.

In mathematical terms:

Energy Savings = Current Energy Use x S x A x $(P-P_c)$

where S = technical savings potential (fractional reduction)

A = fraction of energy use to which measure is applicable

P = future penetration of the measure into the floor space (P = 1 when maximum possible is achieved)

P_c = current penetration of the measure into the floor space

Potential Demand Savings = energy savings/load factor.

The values of factors A, P_C, P, and load factors used for each technology and building subsector type are given in Appendix B. The individual technology profiles describe the basis for each factor and provide total consumption and demand savings for each technology. Consumption and demand savings are summarized in Section 5.

The applicability factors for each technology are derived from the references in the Bibliography. In cases where no information was available, an estimate of application factor was made based on Engineering Interface experience.

As an example, one record in the database contains information on high efficiency central cooling equipment. This equipment provides a reduction of 18% in energy use compared to the conventional equipment. We are also able to estimate that this technology has an applicability factor of 50% in office buildings. It is estimated that currently 10% of the systems installed can be defined as energy efficient. It is also estimated that by 2000 this will rise to only 20% without appropriate incentives. Given this information the database records the following:

Measure	:	High Efficiency Central Cooling Systems
End-Use	:	Space Cooling
Building Sector	:	Office
Fuel Type	:	Electric
Vintage	:	All Existing Building Stock
Current (1985) Electrical Energy Use	:	901,295 MWh (from Appendix A)
Energy Saving(S)	:	18% (compared to conventional technology)
Applicability(A)	:	50% (applies to 50% of all office cooling energy)
Current Market Penetration(P_c)	:	10%
Market Penetration in 2000 without incentives	:	20%

When applied to 1985 gross electric load estimates, the above percentages give us:

Savings Potential without incentives

- 901,295 MWh x 18% x 50% x (20% - 10%)
- 8,112 MWh

The potential saving in demand is 6 MW, assuming an average load factor of 20% for the cooling energy use.

The example given above constitutes one record in the database. As various measures are evaluated and added to the system, the database becomes a storehouse of

technological profiles for the energy management measures for building systems. Organized by end-use, building sector, fuel type and vintage, the data lends itself to a wide variety of profiles (i.e., building sector, energy type, year, end-use, or a combination of any of these).

So far the database contains eighteen measures for twelve building sectors, one energy type (electric) and one vintage (1986). The database can readily be expanded as required.

It should be noted that the database determines only the potential savings that might be achieved in the current building stock without any interaction with other measures. The estimation of future savings taking into account differences between new and existing stock and allowing for interaction between measures can only be carried out using more sophisticated energy demand models such as those in use by the Ministry and Ontario Hydro. The three factors used in the database could, however, be used to generate inputs to these models.

Appendix B, contains tables summarizing the following factors used for each technology and end-use:

- the applicability factor (A)
- the estimated current stock penetration rate (P_c)
- the estimated stock penetration rates in 2000 without initiatives (P); and with initiatives to increase adoption (P')
- the load factors.

Initiatives involving Building Codes, Financial Incentives and Information programs are needed to increase the adoption of technology to a higher penetration P'. The estimates of P' for the year 2000 are based on the experience of Engineering Interface Limited and the values of $P'2000$ are believed to be reasonable. The ultimate strength of the Energy Technology Database is not dependent on these estimates. Several estimates of P' can be made to create a sensitivity analysis.

4.3 Cooling and Refrigeration

4.3.1 Applicable Measures and Technology

There are a wide range of measures which relate to reducing the energy used by cooling and refrigeration equipment. These are shown in Table 4.3. Many of the energy reduction strategies are limited in applicability to specific types of buildings, or even a limited range of building sizes within a subsector.

For example, glass doors and plastic curtains for food refrigeration equipment have narrow application to the food-retail and restaurant subsectors. Similarly, thermal storage technologies for cooling demand reduction apply primarily to large office buildings.

The measures selected for inclusion in the database are indicated in Table 4.3. These two measures were chosen on the basis of wide

applicability throughout the subsectors, and good technical savings potential.

Energy reduction strategies for cooling and refrigeration can be classified as follows:

1 - Space Cooling or Refrigeration Equipment and Controls Technologies; and
2 - Space Cooling or Refrigeration Load Reduction Strategies.

The latter category includes energy reduction strategies from other end use categories, such as reducing lighting and motor energy use.

Table 4.3

Cooling and Refrigeration Energy Reduction Strategies

Cooling

High Efficiency Central Cooling Systems *

High Efficiency Unitary Cooling Equipment *

Part Load Equipment Performance Improvement

- staging of machines
- modulate chilled water temperature

Double Bundle Condensors

- use of heat rejected from chiller condensor

Raise evaporator/Lower condensor water temperature

Retrofit Economizer Cycle

Evaporative Cooling

(water spray in air supply system)

Use of cooling tower water in building chilled water circuit

Thermal Storage

Ground or ground water source heat pumps

Refrigeration

Heat gain, cooling load reduction

- insulation, doors, curtains, etc.

Variable speed refrigeration compressor controls

Evaporative pre-coolers for air-cooled condensors

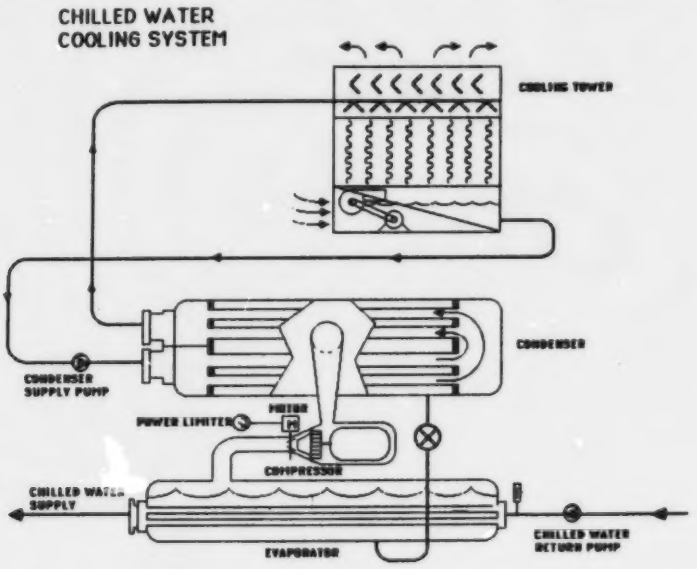
* denotes measures included in database and profiles

4.3.2 Cooling/ Refrigeration Technology Profiles

HIGH EFFICIENCY CENTRAL COOLING SYSTEMS

End-Use: Space Cooling Application: New X

Retrofit X



General Description

Most large commercial buildings provide comfort cooling. Cooling systems consist of a refrigeration machine and some form of packaged air handlers.

Electrically driven refrigeration can be divided into two types of systems - direct expansion systems and chilled water systems. Direct expansion systems like rooftop units, use refrigerant as the cooling medium in coils whereas chilled water systems generate chilled water for distribution to cooling coils.

Many options can be applied to improve the effectiveness and efficiency of cooling systems. Most air handling systems designed for Ontario commercial buildings incorporate free cooling with outside air to reduce mechanical cooling.

Cooling towers can be modified in some cases to generate chilled water in buildings with chiller systems and no outside air free cooling cycle. Free cooling cannot be used effectively above outside air temperatures of 50°F (15.5'C).

Mechanical cooling energy requirement can be lowered with the selection of cooling equipment with increased heat exchange surface for the evaporator and condenser. Better heat exchange will lower temperature differences ("thermodynamic head") between the evaporator and condenser thereby increasing energy efficiency.

Specifications

The efficiency of the cooling equipment can be specified to achieve some minimum level of energy efficiency consistent with life cycle costing techniques. Efficiency is usually specified as Coefficient of Performance (C.O.P.). Independent agencies sanction testing for the reporting of these ratios in manufacturer's literature. Most manufacturers will produce a range of equipment with various degrees of efficiency. The part load performance of the cooling equipment can also be specified to ensure maximum energy efficiency at partial loads.

Field Experience

Energy efficient mechanical cooling equipment is rarely specified by engineering design consultants. Low bid is the primary decision criterion for selection of mechanical cooling equipment. Some engineering consultants do specify a minimum threshold value for energy efficiency of cooling equipment; however, this is not a common practice for small building projects.

There are no standards or guidelines published for COP's of central air conditioning equipment. The range of COP's which can be considered "energy efficient" depends on the capacity of the machine. For large, central systems, a COP of 0.7 kW/ton or lower

is typically considered energy efficient. Chillers now in use in buildings have a COP of 0.8 kW/ton.

Energy Savings

Energy savings for high efficiency cooling equipment varies through a wide range. An energy savings of 18% is typical for the life cycle efficient chiller versus the standard selection chiller. Although the savings indicated are for the chiller device alone, the savings for cooling auxiliary equipment will be similar, if life cycle efficient equipment is selected.

Payback Period

The approximate current cost of mechanical cooling is $300 per ton. The incremental cost for energy efficient systems is about 10%, resulting in average paybacks in the order of 5 years or less.

Applicability

Percent of cooling energy use to which measure applies:

Schools	Univ/Coll	Health	Religious	Other	Offices	Food Retail
11	68	83	2	22	50	11

Other Retail	Hotels/Motels	Restaurants	Recreation	Warehouses
17	39	2	22	1

Barriers

The main barriers to the use of higher efficiency cooling systems in the commercial and institutional buildings are:

- high first cost
- method of specification
- lack of documented performance data
- lack of awareness by those making purchase decisions

Because lowest first cost is normally used in the equipment selection processes for a new building, and the cooling system is an integral part of the HVAC system normally specified by the building design engineer and not the building operator, efficient cooling systems are seldom specified for new buildings. In existing buildings, it is usually not cost effective to replace the complete cooling system to increase its efficiency, so that retrofit packages consisting of, for example, electronic expansion valves and larger heat exchangers, are the only option. These packages have only recently become available, however.

There is also a lack of good monitoring data on buildings which have high efficiency mechanical cooling, making it difficult to compare buildings with different COPs Building designers and operators therefore do not have the necessary documentation to allow them to select new or retrofit cooling systems on a life cycle basis, or feel comfortable with the reliability of high efficiency units.

Lack of awareness of energy efficient options is a chronic problem, especially in smaller cities and towns where those making purchasing decisions do not come in contact with the manufacturers or distributors of more efficient equipment.

An added barrier with non-unitary equipment is that a local system engineer is also involved placing one more step between manufacturer and building operator.

Penetration of Technology

While the efficiency of cooling systems is generally improving, the penetration of high efficiency units on the Ontario commercial/institutional sector is not large. Unless steps are taken to

implement minimum standards or encourage life cycle costing, the penetration in new buildings will continue to be low. Good, Ontario specific performance and cost data also needs to be generated in buildings with high efficiency cooling systems. More retrofit packages need to be developed for existing buildings and again the performance of these systems need to be documented. While these measures may encourage some designers and operators to consider higher efficiency units, a higher penetration is unlikely to be achieved without the implementation of some form of utility rebate system for new and retrofit equipment to provide a less than 3 year payback and to make life cycle costing more attractive. Widespread information programs which reach building operators and engineers in smaller cities and towns are also necessary if province-wide increases in efficiency are to occur.

It should be noted that large numbers of cooling systems built in the 1950s and 60s are coming due for replacement. Action is required now to take advantage of this opportunity. Failure to do so will result in the installation of new low efficiency systems.

The following are estimates of current stock penetration and expected penetration in 2000 with and without initiatives to encourage more widespread use of energy efficient cooling:

		Penetration in 2000	
	Current Penetration	With Initiatives	Without Initiatives
All Building Types	10	40	20

Overall Impact

The estimated annual savings in provincial electricity consumption and demand with and without measures to encourage more widespread use of mechanical cooling are as follows:

	Maximum Possible	With Initiatives	Without Initiatives
Consumption (MWh)	166,000	55,300	18,400
Demand (MW)	115	38	13

Comments

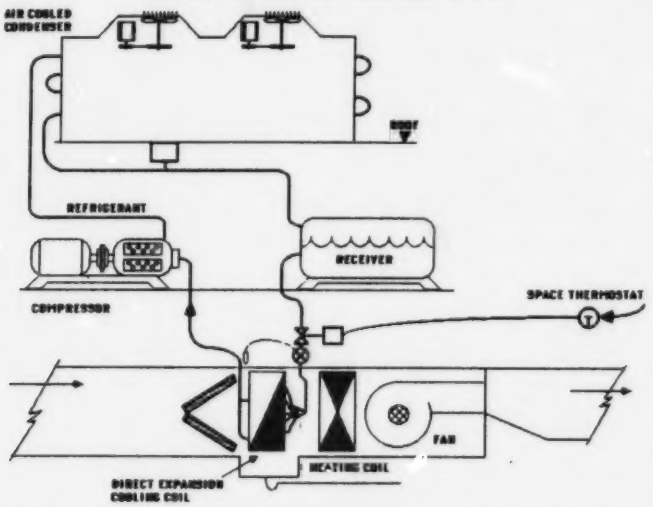
A simple methodology is required to encourage the evaluation of energy efficient cooling equipment during specification and purchase.

HIGH EFFICIENCY UNITARY COOLING EQUIPMENT

End-Use: Space Cooling

Application: New X
Retrofits X

DIRECT EXPANSION COOLING SYSTEM



General Description

Unitary air-conditioning equipment consists of cooling components packaged in factory-fabricated assemblies. Heating equipment is usually incorporated with mechanical cooling in the unit. Unitary equipment uses direct expansion of refrigerant in cooling coils for mechanical cooling.

Three types of unitary air-conditioning equipment are commonly used in commercial buildings: single-packaged, split-system, and packaged terminal.

In single-packaged units, components and controls are packaged in one factory-made assembly. They are available in horizontal or vertical configuration. Roof-mounted horizontal units are more popular than floor-mounted. Air is distributed to the conditioned space through a system of ductwork.

Split system units are the most popular for small commercial buildings. They typically comprise an indoor section and a matching outdoor section interconnected by refrigerant tubing and a thermostat. The indoor section usually consists of a fan, indoor coil, and filter. The outdoor section generally houses the compressor fan, condenser coil and controls.

Packaged terminal air conditioners are designed to serve a room or zone. They are intended for through-the-wall applications. Most unitary equipment manufacturers offer both standard and "high-efficiency" models. Enhanced efficiency is obtained by using multispeed compressors, energy-efficient fan motors, and automatic night setback and morning warm-up controls. Roof-mounted, single-packaged units are available with economizer cycle controls which permit the use of outdoor air for cooling when outside conditions permit.

The efficiency of unitary air-conditioning equipment is indicated by its energy efficiency ratio (EER). The EER is calculated by dividing the cooling capacity (Btuh) by the power input (in watts) at a given set of rating conditions. The EER is expressed in Btuh per watt.

EERs of equipment available from various manufacturers are listed in the "ARI Directory of Certified Unitary Air Conditioners, Heat Pumps and Sound-Rated Outdoor Unitary Equipment," and "ARI Directory of Certified Applied Air-Conditioning Products."

For unitary equipment with capacity of less than 65,000 Btuh the ARI Directory also provides seasonal energy efficiency ratios (SEERs). These are calculated using the U.S. Department of Energy's testing procedures and represent a measure of seasonal operating efficiency. The SEER is the ratio of total seasonal cooling energy requirement to the total seasonal energy consumpt-

ion. The SEER is expressed in Btu per watthour.

Energy-efficient single-packaged rooftop and split systems are available for cooling capacities ranging from 3/4 to 115 tons. Their SEER's currently range up to 11 Btu/Wh. Packaged terminal air-conditioners are available with cooling capacities of 0.5 to 1.5 tons with EERs of 8 to 11 Btu/Wh.

Specifications

Energy-efficient packaged rooftop-type air-conditioning units are particularly well suited for single-storey buildings such as schools, banks, bowling alleys, office buildings, department stores, restaurants, and motels. Packaged terminal units are more frequently used in condominiums, office buildings, hotels, motels, nursing homes, and individually metered multi-storey buildings, as well as building spaces which require individual zone control.

Unitary equipment of all types can be used in both new and existing buildings, and for renovation and expansion projects.

Energy-efficient unitary air conditioning units are reliable, with a life expectancy of 15 to 20 years. Most major manufacturers of unitary equipment currently offer higher efficiency models, through the same distributors as standard products. Energy efficient equipment must be specified using the EER value certified by ARI.

Field Experience

Energy efficient mechanical cooling equipment is seldom specified by owners or design consultants. Low bid is the primary selection criteria for unitary equipment. Multiple building owners such as developers or retailers will often standardize the selection of unitary equipment and incorporate energy efficiency criteria in their standard selection. Some incentives are needed to overcome the low bid mentality of the equipment selection process.

There are no enforced standards for energy efficiency of unitary air conditioning equipment. Most suppliers provide EER data for their equipment. Unitary air conditioners of different sizes have different ranges of EER's. For examples, the EER for a 8000 Btuh terminal air conditioner could range from about 5 to almost 10 Btu/Wh. A unit with EER greater than about 8 would be considered energy efficient.

Energy Savings

Average energy savings for installation of energy efficient unitary air conditioning equipment rather than standard equipment are estimated at an average of 12%.

Payback Period

The cost premium of high efficiency unitary cooling equipment varies according to size and type of unit. Premiums of 10 to 15% are typical. In some cases, there may be no premium. Depending on the equipment and its application, the cost premium should be paid back in 2 to 3 years.

Applicability

Percent of cooling energy use to which measure applies:

Schools	Univ/Coll	Health	Religious	Other	Office	Food Retail
78	39	22	53	67	50	83

Other Retail	Hotels/Motels	Restaurants	Recreation	Warehouses
72	50	64	67	77

Barriers

The major economic barriers limiting the increased use of more efficient unitary air conditioning equipment in existing buildings are as follows:

- the cost of replacing a complete unit when only certain components contribute to the increased efficiency
- the seasonal use of unitary air conditioning equipment in Ontario commercial or institutional buildings

Both of these factors contribute to long paybacks in most types of commercial buildings.

In new buildings, the cost effectiveness is improved because only the cost premium of the more efficient unit needs to be considered rather than the replacement cost. However, the seasonal use of unitary equipment still reduces the savings that can be achieved. In new buildings the split incentive between the building designer who specifies equipment and the building owner who pays for energy use is also a barrier to more widespread specification of efficient units.

All unitary air conditioning equipment sold in Ontario is tested to CSA standards to determine the Energy Efficiency Ratio (EER). However, no seasonal efficiency is determined, and no annual catalogue of product EER or SEER ratings is published. This also acts as a barrier to the selection of more efficient units by building designers, owners, or managers. There is a general lack of awareness that energy efficient unitary equipment is available. This is exaggerated by the fact that most distributors are simply order-takers and building operators seldom deal directly with manufacturers.

Penetration of Technology

There has been a general improvement in the efficiency of all unitary air conditioning equipment over the past few years, partly due to the development of improved designs to meet minimum efficiency standards for consumer and commercial units in some U.S. States. This has also led to increased research and development

on units which use dual or variable speed motors, multistage compressors, and improved heat transfer surfaces. Currently about 10% of the unitary air conditioning equipment installed in Ontario buildings have EERs of greater than 10 BTU/Wh.

The more widespread use of these more efficient units will depend on the existence of a standard Canadian measure of seasonal energy efficiency rate (SEER) and more widespread publication of these ratings through an annual catalogue similar to that published in the United States by ARI. In new buildings and in existing buildings where replacement units are required, increased usage of efficient units could be achieved through the establishment of legislated minimum efficiency standards and the use of loan, rebate, or third party financing schemes that would compensate for any long paybacks involved.

It should be noted that large numbers of unitary air conditioning systems installed during the 1950s and 60s are coming due for replacement. Failure to act now will result in a great deal of cost-effective savings potential being lost.

The following are estimates of current stock penetration and expected penetration in 2000 with and without initiatives to increase the use of energy efficient unitary air conditioning equipment:

		Penetration in 2000	
	Current Penetration	With Initiatives	Without Initiatives
All Building Types	10	40	15

Overall Impact

The estimated annual savings in provincial electricity consumption and demand with and without measuring to encourage more widespread

use of energy efficient unitary air conditioning equipment are as follows:

	Maximum Possible	With Initiatives	Without Initiatives
Consumption (MWh)	191,200	63,700	10,600
Demand (MW)	134	45	7

Comments

Many types of specialized unitary air conditioners are currently offered, including those designed for use with variable air volume (VAV) systems and for multizone systems.

The efficiency of packaged unitary air-conditioning systems is improved when used in conjunction with variable air volume air distribution systems. This approach permits a reduction in fan energy consumption. It is practical in buildings which experience part-load system operation for a large part of the day and have multiple control zones and a common return air path. Economizer controls, which can also result in energy savings, are available as an option in single packaged systems which exceed 20-ton capacity. Temperature-based (dry bulb) economizer controls are typically more economical in dry climates. Enthalpy controls (which measure total heat content of outdoor and return air) are more economical in areas experiencing high humidity.

4.3.3 Cooling Emerging Technologies

The control of cooling systems offers the greatest potential for future improvements in energy efficiency. Most current systems use a mechanical expansion valve to control refrigerant flow in the system. The mechanical valve is modulated by a temperature sensor placed in an appropriate place in the system. This valve is now being replaced by an electronically operated refrigerant valve for better control.

The electronic refrigerant control valves offers a number of significant improvements. The temperature sensors used are more precise and provide better temperature control. The electronic/valve control mechanism can be programmed to optimize control strategies. Finally, the pulsing operation of the electronic valves requires no refrigerant head pressure for system operation. The reduction of head pressure in the refrigerant system will result in greater energy efficiency. A number of electronic controls are being incorporated in new equipment and controls are also available for retrofit applications.

Defrosting cycles for refrigeration systems are being revised to improve energy efficiency. The newer electronic control systems make new defrost control strategies cost efficient. Manufacturers of equipment are currently doing research to find better methods for the current to the coil fan to sense resist-

4.4 Lighting

4.4.1 Applicable Measures and Technologies

Lighting energy end-use provides the richest spectrum of energy management opportunities. The opportunities relate largely to the recent explosion in energy reducing lighting devices based on electronic technology, and the significance of lighting energy use in commercial and institutional buildings.

Electrical energy consumption consists of two components: power loading, and time of use. This is described symbolically by the formula:

kWh = kW x hours

Based on this fact, strategies for reduction of lighting energy use can be classified as:

1 - load reduction (kW)
2 - optimization (kW and hours)
3 - reduction in hours of use (hours)

The sequence in which energy reducing measures are implemented is significant in determining the energy saved. Maximum benefits will be achieved when lighting measures are implemented in the sequence outlined above.

Table 4.1 lists a wide range of lighting energy reduction measures. The measures are classified according to load reduction, optimization, or reduced hours of use. Load

reduction measures are implemented first since the cooling and heating systems must respond to maximum installed lighting loads. Air balancing for example, should only be considered after lighting load reduction measures have been considered and implemented. The air handling system can then be adjusted to the revised load.

Lighting energy reduction strategies for new buildings are incorporated into the design of the lighting system. Efficiency of lighting systems in new buildings relates to the function of the space. The complex interrelationship of light quantity and quality is important for all lighting measures.

TABLE 4.4

LIGHTING ENERGY REDUCTION OPPORTUNITIES

Load Reduction

Low Wattage PAR Lamps *

Screw-in Fluorescent Lamps *

Energy Efficient Fluorescent Lamps*

Energy Efficient Fluorescent Ballasts*

High Efficiency Luminaires & Fixture Removal*

Add on Ballast Devices

- reduce light output and power drawn by fluorescent lamps by a fixed amount

Delamping

Conversion of Incandescent to Fluorescent Fixtures

Conversion of Incandescent to HID

Optimization

Task-Ambient Lighting Systems

Daylighting *

Reduction in Hours of Use

Light Switching *

Occupancy Lighting Controls *

Lighting Automation *

* denotes measures included in database and profiles

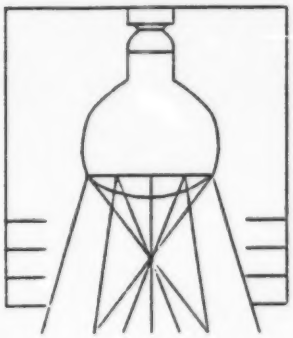
4.4.2 Lighting Technology Profiles

LOW WATTAGE PAR INCANDESCENT

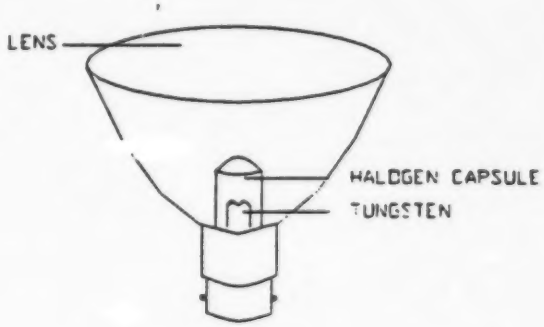
End-Use: Lighting

Application: New X
Retrofit X

ELLIPTICAL REFLECTOR LAMP



HALOGEN REFLECTOR LAMPS



General Description

Incandescent lamps used in pot lighting and decorative applications are designated as "PAR" for parabolic or "R" for reflector. Both have sealed in reflectors for light beam control. Due to different construction, PAR lamps are tougher and offer more precise beam control.

Two types of modifications have been made to PAR lamps to make them more energy efficient:

Type 1. Revised reflector design which concentrates light beam, reducing stray, wasted light.

Type 2. Replacement of standard filament with tungsten halogen capsule, allowing higher filament temperature for improved lamp efficacy.

The reflectors of "R" lamps have been modified to an elliptical shape. These "ER" lamps focus the light pattern so that less light is lost within the fixture, such as for pot lighting applications. The average light output for ER lamps is equal to that of the R lamps replaced.

Specifications

Type 1 low wattage PAR lamps are available in 55 and 65 Watt flood and spot lamps to replace 75 Watt conventional lamps, 80 Watts to replace 100 Watt conventional PAR lamps, and 120 Watts to replace 150 Watt conventional lamps.

Tungsten halogen PAR lamps are available in 45 and 90 Watt flood and spot lamps, to replace 75 and 150 Watt conventional PAR lamps, respectively. ER lamps are available in 50, 75 and 120 Watt sizes to replace 75, 150 and 300 Watt flood and spot R lamps, respectively. Lamp life for all PAR, R and ER lamps is 2000 burning hours. Long life lamps can be specified, which last 6000 hrs, and produce approximately 10% less light output.

Field Experience

The low wattage PAR lamps have produced good results in retail lighting applications. The reduction of heat output in retail stores helps to reduce cooling loads and cooling energy use. Long life lamps are preferred due to the maintenance cost considerations.

Energy Savings

Type 1 PAR lamps reduce lighting energy by 13 to 20%, depending on original lamp wattage and replacement lamp manufacturer. Type 2 PAR lamps reduce lighting energy by 40%.

ER lamps reduce lighting energy use by 33% to 60%, depending on wattage. The higher the original lamp wattage, the greater the savings.

Typically, savings from this measure average about 45% of lighting energy use.

Payback Period

The cost premium for more efficient reflectorized lamps is typically 30 to 50 percent, depending on type and quantity purchased. On the average, this cost premium is paid back within two years. Specific payback periods could be longer or shorter, depending on the hours of operation of the lamps.

Applicability

Percent of lighting energy use to which measure applies:

Schools	Univ/Coll	Health	Religious	Other	Office	Food Retail
1	1	1	10	1	1	1

Other Retail	Hotels/Motels	Restaurants	Recreation	Warehouses
8	3	10	2	1

Barriers

Because PAR lamps are used mostly for special lighting applications, and users are accustomed to paying a premium price, the additional cost to gain energy efficiency in a PAR lamp is less of a barrier than it would be say in more general lighting applications. The wide diversity of PAR lamps in the market and the lack of good information on efficient units do act as barriers, however. Unless users find energy efficient versions of the PAR lamps which also suit their specific task and aesthetic requirements, it is unlikely that the number of efficient lamps sold will increase significantly.

In general there is also a lack of awareness that energy efficient PAR lamps exist. This is exaggerated by the fact that most users purchase lamps from wholesalers or retailers and not directly from the manufacturers who would be expected to provide information on the lamps. Finally, PAR lamps are experiencing competition from quad tube screw-in fluorescent lamps.

Penetration of Technology

The energy efficiency of PAR lamps is improving with new reflector designs and the introduction of tungsten halogen capsules. The penetration of these more efficient PAR lamps into the commercial/institutional sector is quite small at present, and, as stated above, is more likely related to how well these units meet task and aesthetic needs of building operators. This is likely to continue in the future.

A catalogue of low wattage PAR lamps would help raise the awareness of building operators. Since a large proportion of PARs are purchased by the retail and restaurant subsectors, information should be directed to this market. This should be done through volume purchasers such as wholesalers and large retailers.

The following are estimates of the current stock penetration of low-wattage PAR lamps and the expected stock penetration in 2000 with and without initiatives to increase stock penetration:

	Penetration in 2000		
	Current Penetration	With Initiatives	Without Initiatives
Schools	5	25	15
Univ/Colleges	5	25	15
Health	2	10	7
Religious	1	5	3
Other	5	25	15
Office	10	40	30
Food Retail	10	60	40
Other Retail	30	90	60
Hotels/Motels	5	25	15
Restaurant	2	10	7
Recreation	2	10	7
Warehouses	2	10	7

Overall Impact

The expected provincial annual savings in electricity consumption and demand with and without measuring to increase the penetration of low wattage PAR lamps is as follows:

	Maximum	With Initiatives	Without Initiatives
Consumption (MWh)	136,000	77,400	45,500
Demand (MW)	39	23	14

Comments

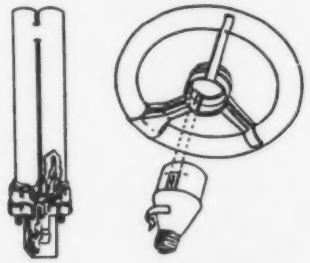
The narrower light beam resulting from energy efficient modifications is desirable for most decorative applications. In some situations, such as wall washing, the change in lighting pattern may produce an aesthetically undesirable effect.

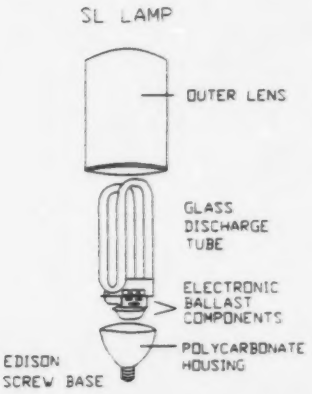
This measure will overlap with screw-in fluorescents since compact fluorescents can be used in some applications now using sealed in reflector lamps.

SCREW-IN FLUORESCENT REPLACEMENTS FOR INCANDESCENT

End-Use: Lighting

Application: New X
Retrofit X





General Description

Screw-in fluorescent technology includes the three types of products illustrated above (A) circline, (B) PL (core/coil) compact lamps and (C) SL (solid-state) compact lamps. All types consist of a lamp and ballast package that can be placed into a medium-size Edison-type base. The circline and SL lamps have an integrated ballast while the PL lamps can have an integral or separately mounted ballast. The circline lamps are typically 8 to 12 inches in diameter and can weigh up to two pounds, thereby limiting their application in commercial buildings. The compact lamps are smaller and lighter. However, their increased length over the incandescent lamps they replace, can limit their application in existing fixtures.

Specifications

The circline is available in 22, 44 and 18/44 two-way sizes for replacing 60, 100 and 50/100 Watt incandescent. The circline provides lumen efficacies in the range of 35 to 40 lumens/Watt.

Circlines range in price from $15 - $30. Compact lamps are available in 5, 7, 9, 13 and 18 Watt sizes, to replace 25, 40, 60 and 75 Watt incandescent lamps. Compacts provide lumen efficacies in the range of 30 to 60 lumens/Watt. The SL lamps are typically $10 - $15 and the PL lamps range in price from $20 - $40. Screw-in fluorescent lamps last considerably longer than the incandescents they replace. The circline is rated at 7,500 to 12,000 hours with a rated ballast life of 50,000 hours. The compact lamps have rated lives of 7,500 to 10,000 hours. By comparison, incandescents are rated in the range of 750 to 2,500 hours.

All lamp types have a lower power factor than incandescent lamps, typically in the range of 60% - 90%.

All lamp types are available in cool white and warm white phosphors.

Field Experience

Numerous retrofit packages are being made available for commercial building applications, such as pot lights and exit signs. Luminaires designed specifically for screw-in fluorescents are now readily available for both retrofit and new design applications. The maintenance benefits due to longer lamp life are accelerating the use of the new lamps. Problems with operation of these lamps in cold weather may occur in outdoor applications.

Energy Savings

The energy savings for this measure will vary with the manufacturer of the product. Typically, the replacement fluorescent product uses 70% less energy than the incandescent lamp it replaces. The power drawn by the ballast must be taken into account when calculating energy savings percentages.

Payback Period

Initial replacement of incandescent lamps with screw-in fluorescents includes lamp, ballast, and possibly fixture, depending on the application. Therefore, the initial cost of installation can range from about $15 to $50. Thereafter, only lamps require replacement, at a cost of about $7 to $8, depending on quantity purchased. The first cost typically pays back within five years, depending on hours of operation. The payback period for lamp replacement alone is considerably lower.

Applicability

Percent of lighting energy use to which measure applies:

Schools	Univ/Coll	Health	Religious	Other	Office	Food Retail
10	5	3	51	5	6	5

Other Retail	Hotels/Motels	Restaurants	Recreation	Warehouses
32	28	26	5	5

Screw-in fluorescent lamps are most economic where the existing incandescent lamps must operate long hours, or continuously. Because the lamps last up to 10 times as long as incandescent lamps, they are well suited to locations where lamp replacement is difficult and expensive.

Barriers

The most significant barrier confronting this technology is its high initial price compared to incandescent bulbs because of the necessity to purchase both ballast and lamp. In addition, none of these lamps can currently be used as point sources and consequently do not provide a good substitute for incandescent spot lamps. This is likely to change, however, with the introduction of screw-in quad tube fluorescent lamps.

There is also a general lack of awareness about screw-in fluorescents among building architects, designers, and managers. While the market is very large, the savings are significant, and most manufacturers are small new aggressive companies; building operators tend to deal with larger lamp distributors and buy in bulk.

Penetration of Technology

Screw-in fluorescent replacements have only recently been introduced into the Canadian market and have, therefore, achieved only minimal market penetration. The market is diverse and rapidly changing.

If this technology is to achieve increased market penetration, it will be necessary to both improve its current economic return through lower product pricing as well as promote its longer operating lifespan and significant savings. This promotion should be directed at wholesalers who supply lamps to the commercial and institutional sector and at building operators in the retail and other subsectors where a large number of incandescent lamps are used and the hours of use per year is high.

While there will continue to be a great deal of industry marketing of screw-in fluorescents, high penetration rates will only occur when large lamp distributors start to carry these lamps.

The following are estimates of current stock penetration and expected penetration in 2000 with and without initiatives to encourage more widespread use of screw-in fluorescents:

	Current Penetration	Penetration in 2000 With Initiatives	Penetration in 2000 Without Initiatives
Schools	5	30	20
Univ/Colleges	5	40	25
Health	5	40	25
Religious	1	6	4
Other	5	30	20
Offices	10	60	40
Food Retail	5	45	30
Other Retail	10	90	60
Hotels/Motels	10	60	40
Restaurants	5	30	20
Recreation	5	30	20
Warehouses	2	15	10

Overall Impact

The estimated annual savings in provincial electrical consumption and demand with and without measures to encourage more widespread use of screw-in fluorescents are as follows:

	Maximum Possible	With Incentives	Without Incentives
Consumption (MWh)	963,400	500,800	309,500
Demand (MW)	289	160	99

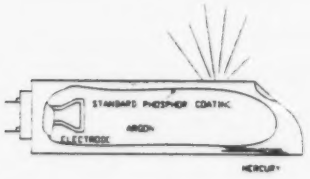
Comments

The market for compact fluorescent lamps is growing steadily. Volume production will reduce the first cost of the lamps and make them cost competitive in applications with lower operating hours.

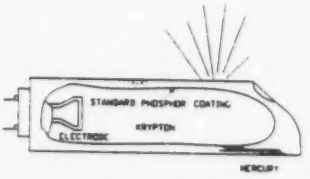
ENERGY EFFICIENT FLUORESCENT

End Use: Interior Lighting **Application:** New X
Retrofit X

STANDARD FLUORESCENT LAMP



TYPE 1 ENERGY EFFICIENT LAMP



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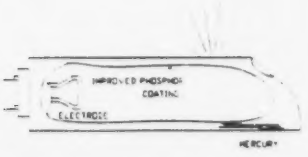
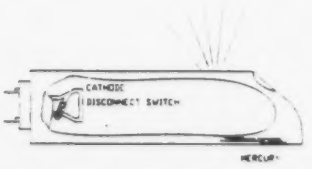


TYPE 3 ENERGY EFFICIENT LAMP



General Description

Fluorescent lamps are available which can be used in place of standard lamps, to decrease the wattage drawn by the luminaire.

There are three generic types of energy efficient fluorescent lamps. Each makes use of different modifications to lamp technology:

Type	1.	Different gas inside lamp (Krypton).
Type	2.	Improved phosphor coating on inside lamp surface.
Type	3.	Disconnect switch on cathode heating circuit.

All of these modifications allow significant reduction in the power drawn by the fluorescent lamp and ballast, with minimal decrease in light output. Thus the lamps have improved efficacy, or light output/wattage ratio.

Specifications

Energy efficient lamps are available in most standard wattages and sizes including 3,4,5, and 8-foot lengths, and U-shapes. Type 1 are available in both "cool-white" and "warm-white" colours. Type 2, which do not reduce light output, are available in "lite-white" only.

Energy efficient lamps have a lower initial light output than comparable standard lamps. The light output of new energy efficient lamps will be higher than the existing lamps, if the existing lamps have logged more than 10,000 hours of operation. Current light levels and lighting requirements for occupants should be determined carefully to prevent any adverse impact on occupants.

Field Experience

The initial introduction of this technology into commercial buildings met with poor experiences. Failure rates of the first energy efficient lamps tended to be higher than the standard lamps they replaced. Ballasts which were close to failure anyway were often "pushed over the edge" by the new lamps. This could result from the higher initial power drawn by either new standard or energy efficient lamps.

Many potential purchasers are confused by the variety of lamp options available from manufacturers. Problems with lamp/ballast combinations have given a bad reputation to these lamps. Lamps used in ambient temperatures below 60°F (15.5°C) will discolour and turn grey.

The issue of whether to replace lamps as they fail (spot) or to relamp entire portions of the building (group) is also a source of confusion. Labour costs typically make group replacement more cost effective.

Energy Savings

Energy efficient lamps decrease lighting energy use by 10 to 20% with a decrease in light output of about 7 to 13%. The average savings in lighting energy use is about 10%. This savings percentage is typical of Type 1 high efficacy lamps, which are compatible with most existing fluorescent ballasts.

Payback Period

The premium cost of energy efficient fluorescent lamps over standard lamps ranges from 0 to 30%, depending on the quantity and type purchased. The cost premium of the energy efficient lamps typically pays back within one year, depending on the hours of lighting operation.

Applicability

Percent of lighting energy use to which measure applies:

Schools	Univ/Coll	Health	Religious	Other	Office	Food Retail
77	87	82	21	56	88	88

Other Retail	Hotels/Motels	Restaurants	Recreation	Warehouses
56	28	11	67	41

Barriers

The major barriers to more widespread use of energy efficient fluorescent lamps include:

Information and Awareness

- There continues to be a general lack of awareness among many building owners/operators of energy efficient lamps and associated cost savings, particularly in smaller urban centres.

- Lighting costs, though frequently significant in absolute terms, typically represent a very small portion of total annual building operating costs. Thus sophisticated financial management is required to identify and substantiate this cost saving opportunity.

- Problems with compatibility, spectrum of choice, cold weather operation, and some early unit failures have limited the popularity of energy efficient lamps.

Initial Cost/Payback

- A large portion of the market continues to employ least first-cost criteria in their lamp selection and procurement practices. Thus, energy efficient lamps, which generally are priced 5-10% over conventional lamps are at a price disadvantage.

- Even where energy efficient lamps are considered, virtually all managers require a payback period of less than 2 years and many require it to be less than 1 year.

Split Incentive

- Many lease arrangements result in a split incentive between the owner/leaser, thus compounding the above barriers and further reducing motivation.

Generally, smaller buildings where energy costs are typically smaller and where in-house financial and technical resources are often less sophisticated, pose a more difficult market to penetrate. Further, the existing market is typically more difficult to penetrate than the new market, where a wider variety of options are available.

Penetration of Technology

A recent report prepared for E.M.R. estimates that energy efficient lamps (4 ft) accounted for about 23% of 1986 lamp (4 ft) sales in Ontario; this compares with about 24% nationally. The corresponding estimates of market (stock) penetration of energy efficient lamps is estimated to be about 18% of existing floor space. Though the report concentrates on 4 ft. lamps for the office sub sector, sales data are considered to be broadly representative for both 4 ft. and 8 ft. lamp sales across the commercial and institutional sectors.

Under current conditions, industry and prior study projections of future energy efficient lamp market (sales) and stock penetration within existing building space are:

Year:	1990	1995
Sales:	34%	48%
Stock:	29%	44%

The E.M.R. report estimates that with the introduction, in 1987, of a 5 year lamp rebate program (which eliminates the price premium), energy efficient lamp sales in 1995 would increase to 77% and stock penetration would increase to 66%.

Market sales and penetration of energy efficient lamps have been greatest in the larger, owner-occupied professional managed

buildings and within large retail chains where lighting is closely linked with merchandising strategies. Schools, government buildings and offices have been early adopters. Similarly, high efficiency lamp sales and stock penetration have been greater in new buildings, particularly where premium quality, high output lamps provide opportunities for enhanced ambience as well as energy and fixture cost savings.

The following are estimates of current stock penetration and expected penetration in 2000 with and without initiatives to encourage more widespread use of energy efficient fluorescent lamps.

	Current Penetration	Penetration in 2000 With Initiatives	Penetration in 2000 Without Initiatives
Schools	35	85	65
Univ/Colleges	20	70	45
Health	15	60	35
Religious	5	25	15
Other	10	40	25
Office	20	70	45
Food Retail	20	70	45
Other Retail	20	70	45
Hotels/Motels	10	40	25
Restaurants	5	25	15
Recreation	10	40	25
Warehouses	15	60	35

Overall Impact

The estimated annual savings in provincial electricity consumption and demand with and without measures to encourage more widespread use of energy efficient fluorescent lamps are as follows:

	Maximum Possible	With Initiatives	Without Initiatives
Consumption (MWh)	600,000	354,200	177,400
Demand (MW)	171	103	52

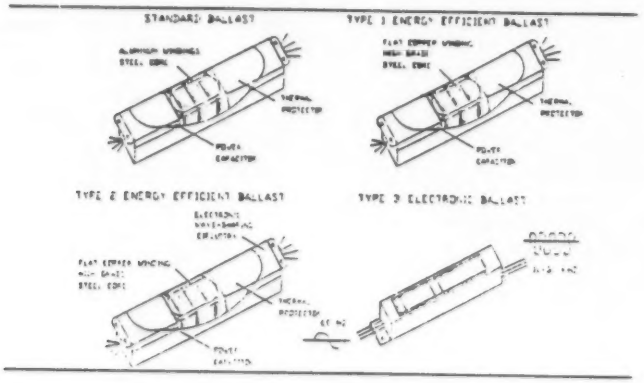
Comments

There is presently no standard for energy efficient fluorescent lamps. The Illuminating Engineering Society warns that high efficacy lamps should only be installed in luminaires that have ballasts designed to accept these type of lamps. Energy efficient lamps should not be used in spaces below 15°C ambient temperature.

ENERGY EFFICIENT BALLASTS

End Use: Interior Lighting

Application: New X
Retrofit X



General Description

Conventional fluorescent ballasts consist of aluminum wire coils and low grade steel core. Three types of ballast have been developed, which improve on this technology to improve ballast efficiency:

Type 1. Coils consisting of flat copper windings, higher grade steel core;

Type 2. As above, with electrical current wave shaping circuitry, to improve lamp performance;

Type 3. High frequency electronic ballasts.

These changes result in lower energy losses for the ballast, less heat buildup in ballast windings and longer ballast life due to lower internal ballast temperatures.

The most commonly used energy efficient ballasts are Type 1. High efficiency ballasts can be used with both standard and high efficacy lamps.

The user should notice no difference in lamp operation or light output with Type 1 ballasts, other than the above noted energy and power savings. Type 2 ballasts will result in increased lamp light output, when used with energy efficient lamps.

Field Experience

Most applications for energy efficient ballasts to date have been new buildings. In existing buildings, government agencies have led in the adoption of this technology. Typically, energy efficient ballasts are installed one at a time, as existing ballasts fail.

Confusion has been experienced over the different energy efficient products available and lamp - ballast compatibility.

Energy Savings

Energy savings average about 10% of lighting energy use compared to standard ballasts for Type 1 energy efficient ballasts, 5% for Type 2 and up to 40% for electronic ballasts, depending on system design.

The average overall energy savings is estimated to be 10%.

Payback Period

The cost premium for energy efficient ballasts ranges from 30 to 60 percent, depending on the type and quantity purchased. The premium is typically paid back in 4 to 6 years.

Applicability

Any standard ballast can be replaced with an energy efficient core and coil ballast.

Percent of lighting energy use to which measure applies:

Schools	Univ/Coll	Health	Religious	Other	Office	Food Retail
66	87	86	25	66	88	86

Other Retail	Hotels/Motels	Restaurants	Recreation	Warehouses
56	30	15	76	46

Barriers

The major barriers relevant to energy efficient core and coil ballasts are similar to those applicable to other high efficiency lighting products. These include:

- General lack of awareness of both lighting costs and the scope of products available for achieving cost savings
- Continued market reliance on least first cost criteria for lighting product selection; hence high efficiency ballasts, which have a higher initial cost (about $6 over a conventional ballast) are at a price disadvantage.
- At present electricity rates, typical payback rates are in the range of 4 years and, therefore, exceed the short (less than 2 years) period demanded by most private firms
- Many lease arrangements result in a split incentive between the owner/leaser, thus compounding the above barriers and further reducing motivation.

The above general barriers are further exacerbated by the relatively long ballast lifespan of about 15 years which results in a much slower (than lamps) "natural" turnover rate. This latter factor primarily affects the retrofit market. Again, as for lamps, smaller buildings are typically more difficult to penetrate in respect of smaller lighting costs and typically less financially and technically sophisticated management.

Penetration of Technology

A recent report prepared for EMR estimates that the current (1986) stock penetration of energy efficient ballasts is in the order of 2% of commercial/industrial floor space. Market (sales) penetration for the same period was 5-10%. To date, virtually all energy efficient ballasts sold in Canada have been the core and coil type; electronic ballasts were not available in Canada in 1986.

Energy efficient ballasts sales in the new building market are significantly higher than for existing buildings and are often sold as a package with premium quality energy efficient lamps and fixtures.

Further, as with energy efficient lamps, the larger, owner-occupied buildings having more sophisticated management, represent the most promising near term markets for energy efficiency ballasts.

Projections of future energy efficient ballast market share and penetration rates, typically are for continued slow growth. Due to their current small market share, however, reliable forecasts of 1995 penetration rates are not available. Realization of increased future penetration rates are contingent on improved economic return through reduced product price and/or increased electricity rates as well as strong product promotion among building designers and operators.

The following are estimates of current stock penetration and expected penetration in 2000 with and without initiatives to encourage more widespread use of energy efficient ballasts.:

	Current Penetration	Penetration in 2000 With Initiatives	Penetration in 2000 Without Initiatives
Schools	2	25	10
Univ/Colleges	2	25	10
Health	1	20	5
Religious	1	20	5
Other	1	20	5
Offices	3	30	15
Food Retail	1	20	5
Other Retail	2	25	10
Hotels/Motels	1	20	5
Restaurants	1	20	5
Recreation	1	20	5
Warehouses	1	20	5

Overall Impact

The estimated annual provincial savings in electrical consumption and demand with and without measures to encourage the use of energy efficient ballasts are as follows:

	Maximum Possible	With Initiatives	Without Initiatives
Consumption (MWh)	736,000	142,200	66,500
Demand (MW)	210	40	19

Comments

An energy efficient ballast will operate at lower temperatures due to lower energy losses. Consequently, the operating life of the ballast is longer than the conventional ballast. Although no long term operating data is available for these ballasts, the life of the ballast should be extended from 50% to 100%. Ballast retrofit will be most economic in the latter stages of existing ballast lifespan.

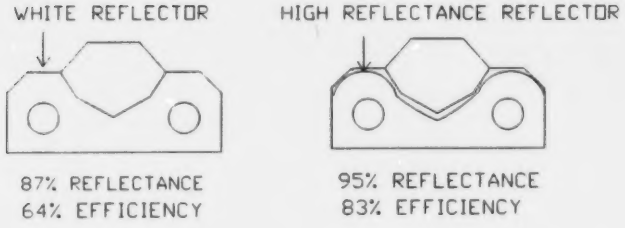
HIGH EFFICIENCY LUMINAIRES

End Use: Lighting

Application: New X
Refrofit X

LUMINAIRE EFFICIENCY

1 X 4 FT
RECESSED LUMINAIRES



General Description

A basic lighting fixture comprises a lampholder, wiring connections, lamp, reflector and lamp housing. A housing with a mirror-like reflectorized internal finish is used with point light sources (incandescent and fluorescent) to control its distribution. In fluorescent fixtures, highly reflective matted finishes are common, providing diffuse lighting. Lenses or louvres also are used to control light distribution and to shield lamps from direct view. Fluorescent and HID fixtures also house ballasts, a device which transforms the input current and voltage characteristics for the specific type and wattage of the gas-discharge lamp employed.

The classification of fixtures is based upon their relative upward and downward components of light distribution. This method identifies six types of fixtures: direct, semi-direct, general diffuse, direct-indirect, semi-indirect, and indirect.

diffuse, direct-indirect, semi-indirect, and indirect.

Luminaires can also be differentiated on the basis of heat dissapation characteristics. An enclosed 2-lamp fluorescent fixture tends to operate lamps "hot", reducing light output and efficiency. Most luminaires are vented to reduce heat buildup and lengthen the life of ballasts.

Reflectors with low light loss can be installed in existing fixtures or new fixtures, to reduce light loss in the fixture. For a retrofit, the new reflector will allow the removal of a fraction of the lamps and ballasts in the space, for equivalent light output. For new applications, fewer luminaires are specified.

Specifications

The lighting efficiency of a luminaire is defined as the percentage of lamp light output delivered by the luminaire to the task. Typical efficiencies for 2-lamp fluorescent troffer luminaires are as low as 60%. Reflectors or lens modifications can increase the efficiency to over 85%. Specifications for luminaire efficiency and design will depend on the nature of the lighting task; however, a minimum luminaire efficiency can be specified for each area of a building.

The advent of high quality specular reflectors makes a reflector retrofit economic where the luminaire operates for a load factor higher than 30% (ie., more than 30% of the hours in a week).

Field Experience

Experience with high efficiency luminaires has been predominantly in new office buildings, and where complete space renovation has been carried out. The type of fixture employed and their layout is highly dependent on the application.

Applications to date have been largely task lighting from drop ceilings, in office buildings. Use of high efficiency luminaires reduces the number of luminaires required to provide appropriate light levels on the visual tasks.

Energy Savings

The energy savings from reflector retrofits can be as high as 50% where 50% of the lamps and ballasts are removed. In most cases, the light level reduction will be too great to permit a 50% energy savings. Typical savings for this measure are 35% of lighting energy use.

Payback Period

The per fixture cost premium of high efficiency luminaires may be as high as 100%. However, because fewer fixtures are necessary, the cost premium of the lighting system is typically less than 20 percent. The fixture cost premium is usually paid back in 2 to 3 years.

Applicability

High efficiency luminaires can be considered when a space is being renovated. Most types of existing fixtures can be retrofitted with reflectors.

Percent of lighting energy use to which measure applies:

Schools	Univ/Coll	Health	Religious	Other	Office	Food Retail
30	40	25	10	25	40	45

Other Retail	Hotels/Motels	Restaurants	Recreation	Warehouses
25	25	5	35	45

Barriers

The use of high efficiency luminaires requires the complete redesign of the lighting system in an existing building or the incorporation of unfamiliar lighting designs into new buildings. Fewer fixtures are used, and the lighting design must be matched to the task to a greater extent. This means that a lighting analysis is required and the building designer and manager must be directly involved. All these considerations act as a significant barrier to the use of high efficiency luminaires, even though the savings are significant. The lighting analysis also adds to the cost of the system and means that installation of high efficiency luminaires can only be carried out during a major renovation.

Other barriers preventing more widespread use of high efficiency luminaires are similar to those applicable to other high efficiency lighting products. These include:

- General lack of awareness of both lighting costs and the scope of products available for achieving cost savings.

- The market continues to rely on least unit first-cost criteria for lighting product selection. High efficiency luminaries add approximately $40-$55 per installed fixture to the initial cost, but when the fewer number of fixtures required is taken into consideration, the total cost is usually the same.

- At present electricity rates, typical payback rates are in the range of 2.6 to 4 years and, therefore, often exceed the short (less than 2 years) period demanded by most private firms

- Many lease arrangements result in a split incentive between the owner/leaser, thus compounding the above barriers and further reducing motivation.

In addition, because they are a relatively new product and no standardized testing and measurement criteria have been developed, there exist competing manufacturer claims related to overall product performance and expected life.

Penetration of Technology

High efficiency luminaires (or optical reflectors) were first introduced to the Canadian market in 1986. Market stock and sales penetration to date are, therefore, minimal. Product sales activity in the U.S. has, however, been very fluid and fast paced since their introduction in 1983. This largely reflects the higher electricity costs prevailing in the U.S.. Unless future Ontario electricity prices increase substantially or other measures are introduced which increase the economic attractiveness of the luminaries, the domestic experience is not expected to follow that of the U.S. Because of the high premium involved, a financial incentive of some kind will be required to ensure a high adoption rate.

Adoption of high efficiency luminaires will likely take place first in the retail, office, and other subsectors which have a large number of buildings with drop ceilings, which lend themselves to lighting remodelling.

The following are estimates of the current stock penetration and expected penetration in 2000 with and without initiatives to encourage more widespread use of high efficiency luminaires:

		Penetration in 2000	
	Current Penetration	With Initiatives	Without Initiatives
All buildings	1	25	10

Overall Impact

The expected annual provincial savings in electricity consumption and demand with and without measures to increase the use of high efficiency luminaires is as follows:

	Maximum Possible	With Initiatives	Without Initiatives
Consumption (MWh)	1,226,400	297,300	111,000
Demand (MW)	356	86	32

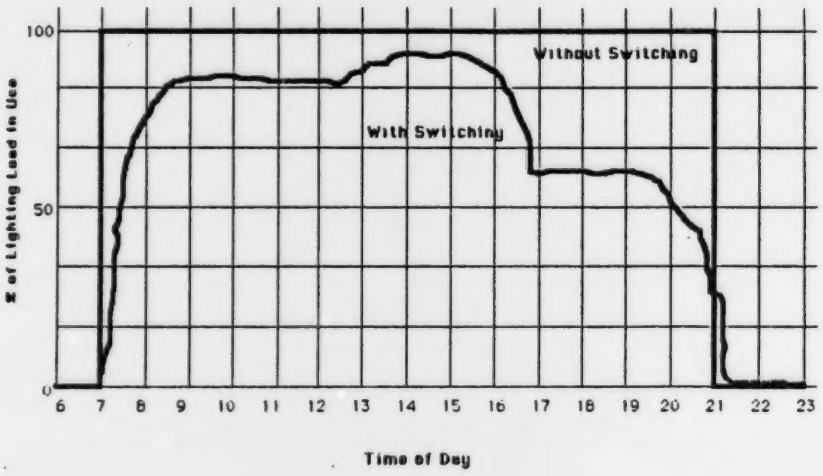
Comments

Fixtures are only one element of a lighting system. To derive maximum efficiency from a system, all components must be considered. In all cases, the lighting system should be designed to provide the best quality illumination for the activities conducted in the space.

LIGHT SWITCHING

End Use: Lighting

Application: New X
Retrofit X



General Description

Installation of light switches provides the opportunity to reduce the energy use of lights which currently operate when the space they serve is not occupied. The most common applications of this measure are in areas such as storage rooms, washrooms, board rooms and classrooms.

Switching has also been carried out effectively in office areas of commercial buildings.

Two types of manual switches are available:

Type 1. Line voltage local switches
Type 2. Low voltage relay switches.

The latter type allows the switch to be located remote from the zone in which the lights are controlled. It is also possible to have one switch control relays for more than one circuit. Electrical conduit is not necessary for wiring this type of system due to the lower voltage (24 V).

In larger buildings, relay lighting controls are often incorporated with a microprocessor based system, allowing time scheduled programming of lighting for different building zones.

Specifications

Manual switches are available in several configurations to meet the specific requirements of the application. Key-activated switches, for example, can be used to prevent unauthorized use of certain lighting circuits. Key switches are advisable for HID applications, where lamps take several minutes to "warm up" after being switched on.

Pull cord, or similar switches should be provided for task lighting so that occupants can switch off their own lights when not required.

Zone light switching via low voltage relays requires that the existing wiring layout is consistent with the floor areas in which lights will be switched simultaneously. This type of system is best applied to wiring where each circuit corresponds to a compact floor area.

Field Experience

Installation of line voltage light switches in existing buildings has typically been more for lighting control than for energy savings. In many applications, the cost of switch installation will not payback quickly enough, based on energy savings alone. The dependence on occupants to use the switches limits their energy

saving potential, especially when the function of the switch is not obvious to the occupant. Labelling of light switches in most installations has been either poor or non-existent. Investment in light switching must be coupled with good labelling to communicate to building occupants.

Low voltage manual switching has been installed in a small percentage of office buildings. The best results with this system have been achieved when an easy to read graphic floor plan accompanies the switches, to clearly show the area controlled by the switch.

Automated low voltage relay systems are meeting with increased application and acceptance, particularly in new office buildings (see Automated Lighting Controls).

Energy Savings

The energy savings for light switching depends on the application and the building operators/occupants. Savings are proportional to the difference between current hours of operation and occupied hours of the switched zone. Typical applications for office space use provide 15% savings in lighting energy use. The office average of 15% savings is expected to be reasonable for other applications such as schools, hotels and hospitals.

Payback Period

Line voltage switches cost in the order of $100 each to install. Low voltage relay system cost approximately 25¢ per square foot installed. Typically, these costs are paid back in 4 to 6 years. Realizing this payback is dependent on occupants using the switches when installed.

Applicability

Percent of lighting energy use to which measure applies:

Schools	Univ/Coll	Health	Religious	Other	Office	Food Retail
50	50	25	10	25	40	46

Other Retail	Hotels/Motels	Restaurants	Recreation	Warehouses
25	25	5	35	45

Barriers

The barriers to increased light switching are primarily economic. If an entire floor or building area is controlled by a single lighting circuit, then increased use of light switching will involve additional costs for rewiring lighting circuits into appropriate zones or sub-systems. While switching can provide cost effective savings, it also requires that occupants do in fact turn off lights when not required. This introduces uncertainty as to whether the potential gains, and hence savings, will actually be achieved. Labelling switches has proven effective in overcoming this limitation. Finally, in some cases, the cost of switch installation will not payback quickly enough based on energy savings alone.

Penetration of Technology

It is estimated that between 20 and 80% of Ontario commercial/institutional buildings have individual switching for specific rooms or zones, depending on building type. The more widespread use of individual switching will depend primarily on electricity costs and the degree to which lighting circuits match local floor usage patterns. It is unlikely that any other initiatives will increase penetration.

The following are estimates of current stock penetration and expected penetration in 2000:

	Current Penetration	Penetration in 2000 With Initiatives	Without Initiatives
Schools	80	80	
Univ/Colleges	60	60	
Health	60	60	
Religious	70	70	
Other	20	50	
Office	20	50	
Food Retail	20	50	
Other Retail	20	50	
Hotels/Motels	40	50	
Restaurant	30	50	
Recreation	35	50	
Warehouses	20	50	

Overall Impact

The estimated annual savings in provincial electricity consumption and demand through the use of light switch is as follows:

	Maximum Possible	Estimated
Consumption (MWh)	290,300	93,800
Demand (MW)	82	27

Comments

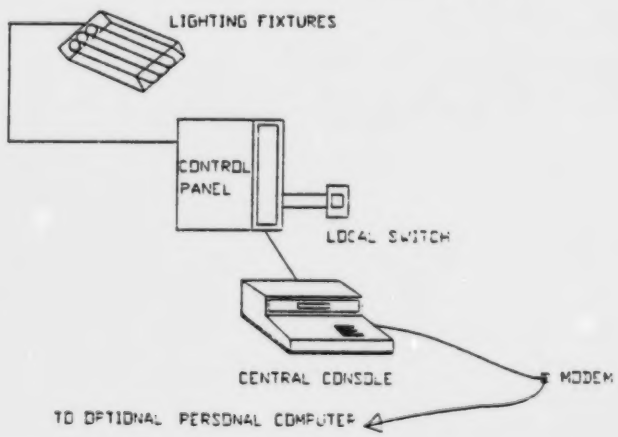
Light switching is already in common use for many commercial building types such as schools. The application of light switching is related to buildings without extensive switching in place.

LIGHTING AUTOMATION

End Use: Lighting

Application: New X
Retrofit X

CENTRALIZED LOW VOLTAGE SWITCHING SYSTEM



General Description

The hours of operation of lighting in different areas of a building can be controlled by means of time schedules, which are programmed into a computer. This method of control is known as a lighting automation system.

The building is divided into zones with similar occupancy patterns. All the lights in each zone are switched on and off together, according to a programmed time schedule. The smaller the zones, the longer the lights in that zone are likely to be switched off, with proportionately greater energy savings. Smaller zones will increase the installation cost of the control system and the complexity of the system. There is an optimal tradeoff point for the number of zones controlled with respect to energy savings and project cost.

Zone lighting is controlled by means of low voltage relays, which receive an electrical pulse signal from a microprocessor. The microprocessor based controls may be centralized for the whole building, or distributed, such as one microprocessor per building floor.

Programmed switching of lights can be overridden by occupants or building operating personnel by means of:

- local manual switches;
- remote manual switch panel;
- a central computer console; or
- touch tone telephone communication with the central computer.

Programmable lighting control can be integrated into a centralized computer which controls other building systems such as fans and chillers.

Specifications

Before proceeding with an automated lighting control system, it should be ensured that the existing lighting circuits correlate well with occupancy patterns. Floors wired with each circuit corresponding to a compact zone of fixtures are much better suited than floors where lighting circuits extend the length of one side of the building.

Attention should also be given to occupant response to the system and the ease with which programmed control can be overridden.

Field Experience

Automated lighting controls are being installed in an increasing number of office buildings, both during construction, and as retrofits. Experience has been mainly in large buildings, where

the magnitude of energy savings could financial justify the cost of a central computer, and the level of effort required for design and tendering. The average size of building in which systems have been installed is about 300,000 square feet.

Application of lighting control systems has been in both owner and tenant occupied buildings. The central computer can be used to log the hours of operation of lights in different zones of the building, allowing tenants to be billed accordingly.

The central computer typically consists of a personal computer, complete with terminal, so that building operators can re program lighting schedule, and check the on/off status of lighting systems.

Many installations of lighting automation systems have been office buildings in which low voltage manual switching was already in place. The capital cost to provide microprocessor controls to interface existing low voltage hardware is lower than for a complete system.

Experience to date has emphasized the importance of giving careful consideration to building occupants when designing and implementing a lighting automation system.

In many cases, occupants must interact with the computer system to keep lights on when they occupy the space outside of the programmed hours. This is usually achieved through the telephone system. It must be convenient and simple for occupants to do this. They must be well informed about the functioning of the system.

Energy Savings

The energy savings will vary directly with the difference between current hours of lighting operation and the programmed schedule of operation, for each zone. This, in turn, depends on the building

lighting system, building use and occupancy patterns. Typical buildings show lighting energy savings of 20% for automated lighting controls.

Payback Period

Lighting automation systems typically cost about 40¢ per square foot. This cost is typically paid back to energy savings in less than 5 years.

Applicability

Percent of lighting energy use to which measure applies:

Schools	Univ/Coll	Health	Religious	Food Other	Office	Retail
1	11	11	0	6	39	6

Other Retail	Hotels/Motels	Restaurants	Recreation	Warehouses
6	6	6	6	17

Barriers

The main barriers preventing more widespread use of lighting automation systems are as follows:

- Lack of awareness of the benefits of automation systems
- The initial cost for the central computer system which reduces the cost effectiveness in smaller buildings
- The difficulty in assessing the overall benefits of the system and the need for an effective lighting system audit and software development
- The mismatch between lighting circuits and potential control zones.

- Competition from other measures such as occupancy controls

The impact of the initial cost can be lessened by assigning part of the cost to non energy related benefits such as the logging of hours of operation, tenant or department billing etc. These benefits can also be used to justify a more extensive audit of current lighting use to assess the overall benefits of the system. The mismatch between circuits and potential control zones is most easily addressed by modifying usage patterns or work areas. In some cases, however, the mismatch may be so great as to eliminate the possibility of an effective lighting automation system.

Penetration of Technology

Potential for adoption of the technology has been strong in both owner and tenant occupied buildings. The central computer can be used to log the hours of operation of lights in different zones of the building, allowing tenants to be billed accordingly.

Adoption has been particularly strong in office buildings in which low voltage manual switching is already in place. The capital cost to provide microprocessor controls to interface existing low voltage hardware is lower than for a complete system. The incremental reduction in lighting hours of operation provided by programmed scheduling usually justifies the capital expenditure.

Lighting automation systems are being used to a much greater extent in larger buildings because of magnitude of the potential savings, and because these savings can justify the purchase of a central computer. It is estimated that about 10% of existing Ontario commercial/institutional buildings and almost half of all large new buildings have some form of automation system. Increased future use of these systems will depend on the availability of lower cost, simpler systems for smaller buildings, and better documented and published rules of thumb that might enable building operators to quickly audit their lighting use and estimate the

potential savings from the purchase of automation systems. A well-designed and implemented user interface which allows building operators to understand and fully utilize the system is the key to increased acceptance and penetration. Standardization and some type of financial incentive would lead to more widespread use.

The following estimates of current stock penetration and expected penetration in 2000 with and without some form of measures to encourage adoption are as follows:

		Penetration in 2000	
	Current Penetration	With Initiatives	Without Initiatives
All Building Types	10	40	20

Overall Impact

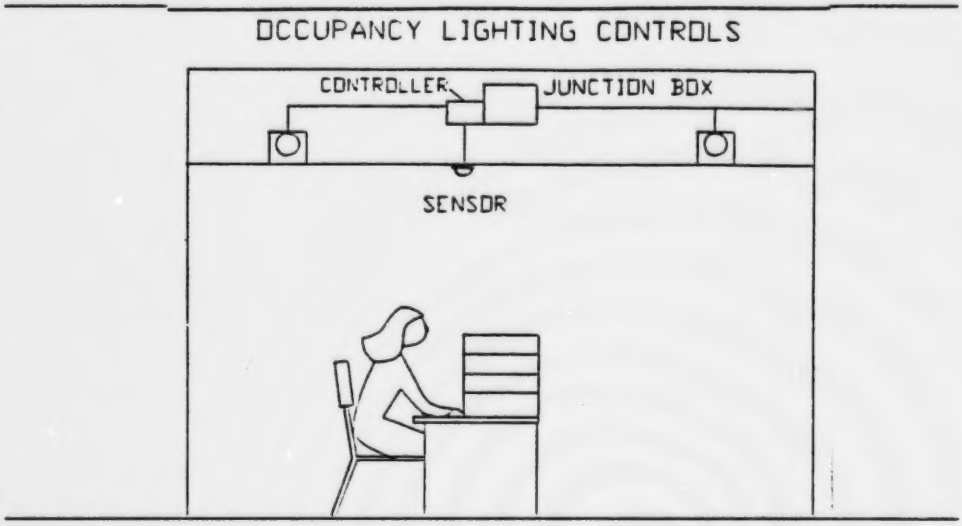
The expected annual provincial savings in electrical consumption and demand with and without measures to encourage the more widespread use of lighting automation systems is as follows:

	Maximum Possible	With Initiatives	Without Initiatives
Consumption (MWh)	369,000	123,000	41,000
Demand (MW)	105	35	12

OCCUPANCY LIGHTING CONTROLS

End Use: Lighting

Application: New X
Retrofit X



General Description

Commercial lighting controls can be used individually to control a specific lighting subsystem or may be part of an overall energy management system which controls other energy building systems.

The control component which determines how the controlled lighting will operate can be of three generic types:

Type 1. Time scheduled signal(see Lighting from microprocessor based Automation) controller
Type 2. Photo sensor(see Daylighting)
Type 3. Occupancy sensor.

The last type of control can be based on four types of sensing technology:

- Ultrasonic
  - activate light circuit when change in ultrasonic beam reflection is sensed.

- Passive infrared
  - activate lighting circuit when body heat is sensed

- Active infrared
  - activate lighting circuit when change in infrared beam reflection is sensed.

- Acoustic
  - respond to sound in frequency range exhibited by "human activities".

Some occupancy sensors combine passive infrared and ultrasonic sensing for more reliable control.

Specifications

Occupancy controls consist of the sensing component described above and the switching component which actually energizes or de-energizes the lighting circuit. Currently available sensing units have a sensing range of 200 to 2000 sq.ft., depending on type and manufacturer. The corresponding switch typically controls a fluorescent lighting load of 1.5 kW, equivalent to about 500 sq.ft. of office space.

Most of the available controls incorporate a delayed shut off response of several minutes so that lights are not switched off in response to the occupant leaving the zone for a very short period of time.

Lighting controls are available from electrical distributors and contractors.

Field Experience

Reliable occupancy based lighting controls have been available for several years. They have been applied effectively in locations such as conference and storage rooms, where occupancy occurs at random and the occupied period is a relatively small portion of the time for which lights would normally be on.

Application is increasing in office space, particularly executive suites, where overall occupancy over the day tends to be lower and varied.

Energy Savings

Typical savings for occupancy sensors are 35% of lighting energy use. Savings will depend on occupancy patterns and the definition of occupancy zone controlled by each sensor.

Payback Period

Occupancy based lighting controls cost in the area of $200 per sensor-controller combination. This cost is usually paid back in the less than 5 years. Specific paybacks depend on the application.

Applicability

Percent of lighting energy use to which measure applies:

Schools	Univ/Coll	Health	Religious	Other	Office	Food Retail
40	30	10	5	15	20	5

Other Retail	Hotels/Motels	Restaurants	Recreation	Warehouses
5	20	0	15	30

Barriers

The major barriers confronting this technology include:

° Lack of awareness about occupancy controls and their benefits

° Lack of design experience and performance documentation

- The appropriate location of sensor controls and optimum design layout of lighting zones are areas of continuing research.

- Further, there is a lack of reliable and representative monitoring data which can be used to adequately substantiate, to building designers/owners/operators, the extent of actual energy and cost savings which can be confidently expected to result from the installation of occupancy lighting controls.

° Competition from other measures such as lighting automation

° Economic Risk

- In both new and existing buildings, the installation of occupancy lighting controls increases the overall lighting capital cost. In some existing buildings, an entire floor or building area may be controlled by a single lighting circuit. In these cases, therefore, installation of occupancy lighting controls would require additional costs for rewiring to create lighting zones which would be compatible with the efficient matching of lighting controls to occupancy patterns.

- In some new buildings (eg. offices) lighting systems are frequently designed and installed without any knowledge of the specific lighting needs of future inhabitants.

Further, even where lighting systems have been matched to occupant needs, changes in occupancy and/or in lighting requirements are common. Unless properly planned for, these changes can result in a loss of return on the initial lighting control investment and/or increase the cost of lighting renovations.

- Thus in the absence of reliable cost-saving data plus the potential additional costs associated with responding to changing occupant lighting requirements, potential economic returns are at risk.

- The above concerns are, of course, exacerbated cases where lease arrangements involve split incentives between owners/leasers.

Penetration of Technology

Very few commercial and institutional buildings have any form of occupancy lighting controls. Future increase in use will depend on the availability of good data showing the benefits that can be achieved, and some form of information program to promote their use. Since lighting automation systems will likely be the preferred choice for lighting control in large buildings, initiatives should be directed at small building owners.

The following are estimates of expected penetration in 2000 with and without initiatives to encourage the use of occupancy controls. Current penetration can be assumed to be zero.

	With Initiatives	Without Initiatives
All Building Types	25	5

Overall Impact

The estimated annual savings in provincial electricity consumption and demand with and without measures to increase the use of occupancy controls are as follows:

	Maximum Possible	With Initiatives	Without Initiatives
Consumption (MWh)	593,000	148,200	29,600
Demand (MW)	172	43	9

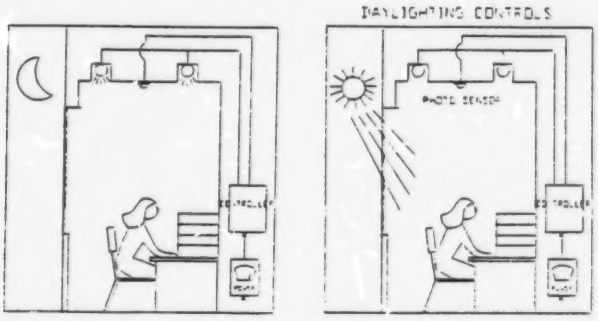
Comments

There is strong potential for use of occupancy controls in classrooms in schools, and similar locations. Retrofit costs are substantially higher than new building installation costs.

DAYLIGHTING

End Use: Lighting

Application: New X
Retrofit X



General Description

Daylight can be used effectively to reduce the amount of energy required to provide suitable light levels. The daylight available for illumination depends upon the time of year, the time of day, and weather conditions. Building design is also a determining factor. This includes the location and size of windows and skylights, the shape of the building, and the corresponding ratio of interior to perimeter floor areas. It also includes the position, shape, and colour of interior partitions, ceilings, floors, and furnishings.

Daylight from perimeter windows can illuminate a zone 20 to 25 feet deep, in a typical building space. Daylight can also be introduced through skylights or atrium roof glazing.

Retrofits to building design which increase daylighting are limited. One retrofit strategy is the installation of skylights in warehouse buildings.

Various devices are available which control the use of energy for artificial lighting when daylight is available. These can be categorized as switching and dimming systems. Both types rely on a photocell device to sense the amount of daylight available.

Dimming of fluorescent lights can be achieved by control of special dimming core and coil ballasts, or by use of the new electronic ballast technology. Although more complex and costly than switching systems, dimming provides more acceptable lighting control.

Specification

Daylighting as an energy management strategy in new building design requires detailed energy analysis to determine cost-effectiveness. Reliance on daylighting requires more glazing (windows or skylights), which can increase heating loads significantly in winter. Solar heat gain associated with daylighting in winter will partially offset the increased heating load. Solar gains in summer can significantly increase demands on the cooling system.

Daylighting strategies also require careful specification to ensure visual comfort of occupants. Glare can be a problem with daylight illumination.

Photosensors are a key component of daylighting systems. The sensor's location in the space, and sensor design are critical. Photosensors are of particular concern in switching systems. If photosensors allow the lights to be switched on and off in response to momentary changes in light level (such as from passing clouds), it will be unacceptable for the occupants.

Field Experience

Many recently constructed buildings incorporate architectural features which make effective use of daylight. In some new office buildings, dimming controls are integrated into central automated control systems.

Photoswitching devices have been installed in selected daylit areas of schools, offices and warehouse buildings. Little or no literature is available on case studies for daylighting practice.

Energy Savings

Architectural features which reduce the installed lighting load compared to conventional building construction, result in both demand and energy savings. Studies by the National Research Council* have shown savings as high as 70% for daylighting from vertical glazing in perimeter areas. Daylighting from overhead glazing can provide savings up to about 40%.

With fluorescent dimming systems, lighting load can be reduced 50 to 70% in daylit areas, depending on whether dimming ballasts or conventional ballasts are used. Energy savings from switching systems are proportional to the hours for which the lights can be switched off. Average overall savings for daylighting applications are estimated to be 50% of lighting use in daylit areas.

Payback Period

The payback period for the capital cost of building design features which incorporate daylighting is difficult to quantify and may range from 2 to 15 years, depending on the building.

Applicability

Percent of lighting energy use to which measure applies:

Schools	Univ/Coll	Health	Religious	Other	Office	Food Retail
37	22	6	0	6	21	5

Other Retail	Hotels/Motels	Restaurants	Recreation	Warehouses
11	0	0	11	47

Barriers

The major barriers to the more widespread use of daylighting include:

- Current building practices and codes. These were designed to minimize the use of daylight as a light source and the use of windows as a means of ventilation.

- A general lack of performance information. There has been very little monitoring of the effectiveness of daylighting systems and few comparisons made between different building designs.

- No design knowledge. Few building designers are capable of utilizing daylight effectively.

- Lack of understanding and awareness. The concept of using window and skylight design and internal layout to increase daylighting's contribution to building electrical loads is not widely understood.

- An unforgiving technology. Until recent advances in window systems which allow more effective control of solar gain and heat losses without sacrificing daylight entry, many attempts to increase the daylighting contribution resulted in uncomfortably hot or cold zones in buildings and high correction costs.

- New and renovation only. It is difficult to increase the daylighting contribution in existing buildings except during a major renovation

Penetration of Technology

For the reasons stated above, there has been minimal use of daylighting to date in commercial and institutional buildings to reduce electrical lighting. With the appropriate steps taken to increase the knowledge of daylighting and to train building designers in its advantages, there could be a growing number of new buildings and renovations that use it.

The advent of electronic ballasts will open the way for more innovative use of daylighting in combination with automated lamp dimming. This should greatly increase the potential for the use of daylighting to save energy in both new and existing buildings.

The action necessary to achieve any significant penetration includes:

- Modification of building codes to encourage or regulate the use of daylighting. In California, the building code has prescriptive instructions regarding daylighting. In Paris, all office building workstations must be no more than 5 metres from a window.

- Integration of daylighting as a primary light source into general building design, operating, and energy management practice;

- Demonstration and documentation of daylighting system performance;

- Development of technical and design skills for daylighting;

- Widespread dissemination of daylighting information to building owners and designers;

- Improve training courses in daylighting for building designers, lighting designers and engineers;

- Continued development of glazing, light pipe, and control systems.

The following are estimates of current stock penetration and expected penetration in 2000 with and without initiatives to encourage more widespread use of daylighting:

	Current Penetration	Penetration in 2000 With Initiatives	Penetration in 2000 Without Initiatives
Schools	20	50	25
Univ/Colleges	10	25	12
Health	10	25	12
Religious	0	10	5
Other	10	25	12
Office	5	20	7
Food Retail	5	20	7
Other Retail	5	20	7
Hotel/Motel	10	25	12
Restaurant	5	20	7
Recreation	10	25	12
Warehouses	15	40	20

Overall Impact

The estimated annual provincial savings in electricity consumption and demand with and without initiatives to increase the amount of daylighting are as follows:

	Maximum Possible	With Initiatives	Without Initiatives
Consumption (MWh)	815,800	163,800	25,200
Demand (MW)	243	50	8

Comments

Caution should be exercised when using dimming controls with existing ballasts. Ballast operation with some dimming devices can fall outside the manufacturer's recommended operating range. Also, high efficacy fluorescent lamps should not be used on fixtures wired to dimming controls.

4.4.3 Lighting End-Use Emerging Technologies

Emerging technologies in the area of lighting energy reduction are largely applications of advancements in semi-conductor technology. The emerging technology which shows the greatest promise is the electronic ballast. These ballasts use solid state circuitry to reduce transformer losses and operate at high frequency to reduce power requirements of fluorescent luminaires. Power drawn by luminaires is reduced by 20 to 25%.

Electronic ballasts are readily available in the U.S. but have not yet penetrated the Ontario market. The technology is expected to become commercially viable in Ontario by about 1990.

Ontario lags the U.S. market for two principal reasons. First, American lighting systems typically operate at 120 or 277 volts. Many Ontario lighting systems are operated at 347 volts, so that American manufactured ballasts cannot readily be used.

The second reason relates to the lower cost of energy in Ontario compared to urban markets in the U.S. The longer payback in Ontario provides little incentive to building owners. Therefore, suppliers are reluctant to introduce the technology to Ontario at this time.

The cost of lighting automation and control systems has been reduced with new microprocessor technology. Lighting automation systems are now specified for 40% of new office buildings. Unfortunately, budget cost pressures for new buildings make investment in new lighting technology the "first thing to drop" in a budget squeeze.

4.5 Motors

4.5.1 Applicable Measures and Technologies

Energy reduction strategies for motors can be placed in three generic categories:

1 - reduction in motor energy use from load reduction
2 - reduction in hours of operation of motors
3 - application of new or improved technologies to motors.

The first category relates primarily to pumps and fans. In existing buildings, over-design in air and water flow is frequently encountered. By trimming fluid flow rates to the amount needed, the power drawn by the motor driving the pump or fan is reduced by approximately the cube of the flow rate.

Hours of operation of motors can be reduced, depending on the hours for which the equipment driven is required to operate. Often it is possible to shut fans and pumps off overnight or during other unoccupied periods. This can be achieved manually, by electro-mechanical time switches or by an energy management control system.

New technologies for motor energy use reduction include energy efficient motors and semi-conductor based motor speed controls.

There are several types of speed controls, using different electronic technologies.

Table 4.5 shows a wide range of energy management strategies which can be applied to motors. The measures selected for technology profiles are indicated.

TABLE 4.5

ENERGY REDUCTION STRATEGIES FOR MOTORS

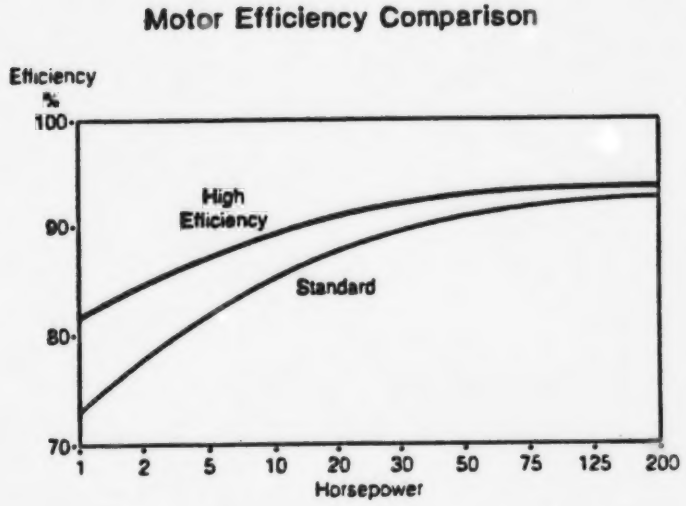
Measure	
Load Reduction	
Air Balancing and Fan Speed Reduction	*
Air Balancing and Flow Throttling by dampers	*
Water Balancing and Pump Impellor Modification	*
Water Balancing and Flow Throttling	*
Reduction in Hours of Operation	
Manual Switching of Motors	
Switching of Individual Motors by Electro-mechanical Timeclocks	
Control of Motor Operation by Energy Management Control System	*
Application of New/Improved Technology	
Energy Efficient Motors	*
Variable Speed Motor Drives	*

* denotes measures included in database and profiles

ENERGY EFFICIENT MOTORS

End Use: Motors

Application: New X
Retrofit X



General Description

Energy efficient motors are also know as high-efficiency and premium motors. They are essentially interchangeable with standard motors, but differences in construction make them more energy efficient.

Energy-efficient (EE) motors achieve their improved efficiency through reduced losses in the conversion of electrical energy to mechanical energy. Magnetic losses are reduced by using thinner steel laminations in the stator and rotor core, as well as more and better grades of steel. The air gap between rotor and stator is also minimized. To reduce resistive losses, energy-efficient motors use more copper in the stator windings. Different manufacturers may use any or all of these improvements in their designs.

Specifications

The greater the run time for a motor, the more likely it is that an EE motor will be cost-effective for an application.

Energy-efficient motors can be applied virtually anywhere that a standard motor would otherwise be used: for fans, pumps, and mechanical cooling systems. New installations allow a wider range of efficient motor applications. For example, some air conditioning and refrigeration equipment has the motor sealed in the hermetic compressor. In most cases, interchanging standard units with EE motors poses no major problems, allowing for broad retrofit applications. Engineers will usually specify some minimum motor efficiency for each specific motor application.

Energy-efficient motors are available from most motor manufacturers, typically in sizes from 3/4 to 200 horsepower.

Field Experience

Energy Efficient motors are considered an economic alternative when new motors are purchased or failed motors are replaced. In most cases, the energy savings cannot justify the full capital cost of the new EE motor. Consequently, retrofits with energy efficient motors are restricted to a replacement on failure of standard motor situation.

Benefits of EE motors, besides energy savings, include extended motor life due to reduced internal heating. Lower heat output of EE motors could also reduce mechanical cooling costs.

Energy efficient motors must be carefully applied to loads which are sensitive to speed because they have lower slip values than standard units, and thus run at a slightly higher speed. For example, a centrifugal fan's power requirement increases with the cube of its speed. If the EE motor runs 1% faster, (which is

typical) there will be an increase in both the airflow and the power required of about 3%. This could negate the savings from increased motor efficiency. In this case, modifying the fan pulley would be in order to keep its speed constant.

Energy Savings

Energy savings vary from 12% for a 1 HP motor to only 4.5% for a 100 HP motor. Typical motors in most commercial buildings are in the 10 HP range with a 7% savings in motor energy. The EE motors also operate at higher power factors which may reduce power factor penalties in some buildings. The following table shows efficiency and power factor for various sizes of standard and energy efficient motors, at full and half load.

TYPICAL MOTOR EFFICIENCIES AND POWER FACTORS

Motor Size		Efficiency		Power Factor	
(HP)		Full Load	Half Load	Full Load	Half Load
1	Standard	72	68	78	58
	EE	84	81.5	80.5	62
2	Standard	75.5	72	78.5	56.5
	EE	84	81.5	81.5	64
5	Standard	81.5	78.5	80.5	65.5
	EE	86.5	86.5	85.5	71
10	Standard	84	81.5	85.5	75
	EE	90	90	89	79
20	Standard	88.5	88.5	84	75
	EE	92	92	88	82

Payback Period

The average price premium for energy efficient motors is about 25 percent in the low horsepower range, dropping to about 5 percent in the higher horsepower range. Some motor manufacturers who offer "energy efficient" motors may still regard them as "specialty" items.

In such cases, long delivery times and price premiums of 50 percent or more can be expected. (The quantity of motors purchased, however, can be a factor in reducing the "specialty" price premium).

Depending on the size of motor and hours of operation, payback periods typically range from 8 months to 4 years.

Applicability

Percent of motor energy use to which measure applies:

Schools	Univ/Coll	Health	Religious	Other	Office	Food Retail
66	77	82	50	60	77	61

Other Retail	Hotels/Motels	Restaurants	Recreation	Warehouses
51	66	51	61	51

Barriers

There are a number of barriers which are limiting the adoption of energy efficient motors:

- There is a general lack of awareness about energy efficient electric motors, particularly among small building operators.

- Electric drive power consumption costs, though frequently significant as a fraction of electricity costs, typically represent a relatively small portion of total building operating costs.

- Lowest first cost for the highest quality remains the predominant basis of motor choice by the end-user. In this case, quality is defined primarily in consideration of factors such as reliability, availability, service/warranty etc. in respect of the potential production line costs (losses) associated with motor failure.

- In as many as 50% of all cases, the end-user has no role in motor selection, as the motor is supplied integrally with another piece of equipment (e.g. HVAC unit air mover or compressor motor). The manufacturer of the original equipment (e.g. HVAC unit) is not the end-user or hence, responsible for energy costs. Their predominant selection criteria is, therefore, reliable service at lowest cost, not energy efficiency. In these cases, the end-user of the motor is typically relatively unsophisticated concerning the technical characteristics of the motor.

In general, the larger end-user who purchases direct tends to be technically and financially more sophisticated and, given the larger motor size, can afford to devote more careful analysis to motor selection. However, even in this case, the absence of a commonly accepted and widely used motor efficiency standard has resulted in numerous different definitions of high efficiency and a multitude of efficiency claims leading to skepticism on the part of motor users.

Penetration of Technology

Specific market penetration data for energy efficient motors are not available; however, manufacture and utility sources estimate that energy efficient motors currently represent about 5% of all motor sales, but the majority of these sales are for the larger, industrial units. Given the typically smaller units employed within the commercial and institutional sectors, current energy efficient motors sales and stock penetration in Ontario are, therefore, assumed to be minimal. In the United States, about 10 to 15% of motor sales to the commercial sector are energy efficient units.

Future penetration rates are expected to remain very small unless active program measures are introduced, such as:

- development of energy efficient motor standards and testing procedures

- regulatory intervention defining minimum motor efficiency standards for motors supplied integrally with other equipment

- financial assistance to reduce payback periods to the range of 2-3 years.

These measures should first be directed towards the new and replacement market. To have a more significant impact, however, building operators will need to be encouraged to replace motors before the end of their useful life. Because the normal life of a motor is 20 years, this could double the stock penetration by 2000. In all cases, the incentives must be such that the incremental costs to the building operator are less than the savings that will be achieved. The degree of penetration will be very sensitive to the size of the incentive because of the high cost of motor replacement.

The following are estimates of the current penetration and expected penetration in 2000 with and without significant measures to encourage adoption of energy efficient motors:

	Current Penetration	Penetration in 2000 With Initiatives	Without Initiaties
Schools	2	30	10
Univ/College	3	50	15
Health	3	50	15
Religious	0	25	5
Other	0	25	5
Office	3	50	15
Food Retail	1	25	5
Other Retail	1	25	5
Hotel/Motel	1	25	5
Restaurant	1	25	5
Recreation	1	25	5
Warehouse	1	25	5

Overall Impact

The estimated annual provincial savings in electricity consumption and demand with and without initiatives to encourage more widespread use of energy efficient motors are as follows:

	Maximum Possible	With Initiatives	Without Initiatives
Consumption (MWh)	580,300	206,100	46,700
Demand (MW)	135	45	10

Comments

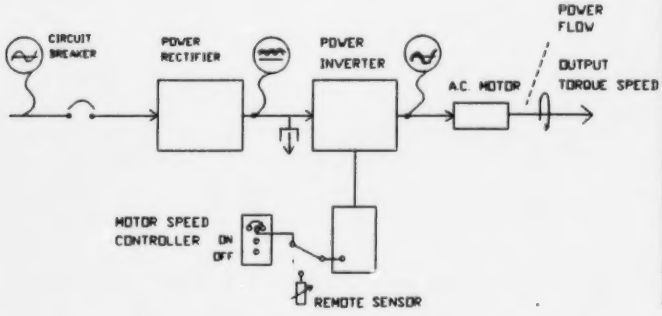
Very old motors (for example, U-frame designs of the 1950's) may be of comparable efficiency to currently available EE units. EE motors are less tolerant of electrical phase imbalances. If phase imbalance exceeds 5%, EE motors should not be used until the imbalance is corrected.

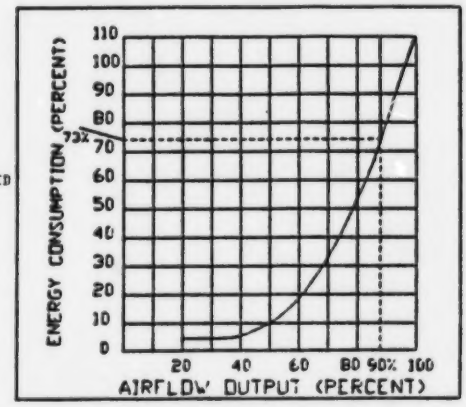
VARIABLE SPEED DRIVES

End Use: Motors

Application: New X
Retrofit X

ELECTRONIC VARIABLE SPEED DRIVE





General Description

Electronic Variable Speed Drives (EVSD's) adjust the speed of the motors they control by electronically varying the input frequency to the motor. Mechanical drives can also be used to vary the speed of motor driven equipment. Mechanical drives typically have lower efficiency, a smaller speed control range, and higher maintenance requirements.

The EVSD is installed on the electrical supply side of the motor. The electrical power supplied to the motor is first inverted to DC then back to AC, at the desired output frequency. The frequency determines the motor operating speed.

The output of the EVSD can be varied in response to manual control, or an automatic control signal in the form of a voltage, current, or pressure.

The operation of the EVSD is unique among variable speed drives in that it maintains a low-slip condition of motor operation (and thus maintains relatively high efficiency and power factor) over a wide range of motor speeds and loads. There is a small energy loss within the inverter components, making EVSD's slightly less than 100% efficient.

Specifications

EVSDs are presently available from many manufacturers, in sizes ranging from 1 to 1500 horsepower.

The design of a EVSD installation is site specific. Therefore, the equipment must be specified to suit the specific application. The key criteria for EVSD specification are:

- input voltage (575V in Canada. EVSD's manufactured outside Canada are for 460V)
- output frequency (speed) range
- overall efficiency
- noise level (including audible noise and electromagnetic interference)
- availability of service and parts

For a new installation, a high efficiency motor should be specified. The EVSD/high efficiency motor is the most energy efficient combination.

Field Experience

Experience with EVSD's in buildings is limited, but growing.

The majority of installations are on variable air volume (VAV) fan systems. There is less experience with fluid pumping applications. The low level of adoption is partly due to a general lack of awareness of the technology and misconceptions regarding equipment cost and reliability.

Energy Savings

The EVSD reduces the speed of the loads so that overall energy and peak power savings can be achieved. The power requirement of centrifugal fans and pumps varies as the cube of their shaft speed. For example, a reduction in speed of 10% results in a 27% reduction in power requirement. Typical savings for commercial buildings are about 60% of the constant speed motor energy.

Payback Period

The cost of electronic variable speed drives varies depending on the size of motor controlled. For motors less than 5 hp, prices range from about $600 to $2500 per hp. For very large motors, (100 to 300 hp) the cost is reduced to a few hundred dollars per hp.

The cost of the EVSD is typically paid back in 5 to 10 years.

Applicability

EVSDs are applicable wherever a varying load calls for a variable speed motor drive. This includes variable-volume air distribution, water pumping, and air-conditioning chillers. They are suitable for both new and retrofit installations.

Percent of motor energy use to which measure applies:

Schools	Univ/Coll	Health	Religious	Other	Office	Food Retail
10	20	10	0	5	20	15

Other Retail	Hotels/Motels	Restaurants	Recreation	Warehouses
5	10	0	5	5

Barriers

The major barriers to the increased adoption of this technology are as follows:

Awareness

- Many building owners as well as "in-house" and consulting engineers are not fully aware of the potential benefits of EVSDs and many have had misperceptions as to their cost and reliability.

Initial Cost/Payback

- Higher initial capital cost combined with the relatively low marginal cost of electricity typically extends the payback beyond the very short period (under 2 years for retrofit projects and 3 years for new buildings) demanded by most private owners.

- Similarly, least first cost purchase procedures combined with split landlord/tenant incentives further reduces motivation.

- Current EVSD pricing appears to be somewhat high due to the limited number of firms and the uniqueness of the products, thereby resulting thus far in a "skimming" of market potential.

Service/Risk

- In some smaller centers, qualified service resources may not be readily accessible, thus further increasing the reluctance of building owners/design engineers to incorporate EVSDs into building designs.

Compatibility

- Constant speed applications require the addition of a controller as well as the EVSD.

Penetration of Technology

A recent EMR study provides the following EVSD market penetration results:

- The total number of installed units in Canada as of January 1, 1986 was about 4000 EVSDs, representing about 750-1000 sites. This represents less than 1% of the assumed total market potential.

- Ontario appears to be a market leader in installed EVSD units.

- Canadian (1985) sales were estimated to be between 700 and 900 units (140-200 EVSD projects); this represents about 3-5% of new sales.

- The rate of Canadian EVSD sales is expected to increase only slowly, reaching about 1600 units by 1990 and about 3200 units by; 1995.

- Payback periods are shorter, the larger the installed unit and the greater the turndown ratios. Under these optimum conditions and marginal electricity rates of 4 cents/Kwh, payback periods of 3-5 years can be achieved. Given a typical public sector payback requirement of 5 years or less, the major near term market for EVSDs is expected to be larger, publicly funded projects.

- In order to increase private sector adoption rates, it is expected that a combination of financial incentives to reduce payback periods (3 years for new; 2 years for retrofit), plus demonstration and/or education projects to overcome lack of awareness/risk aversion barriers would be required.

The following are estimates of current stock penetration and expected penetration in 2000 with and without measures to encourage more widespread use of ESVDs:

	Current Penetration	Penetration in 2000 With Initiatives	Penetration in 2000 Without Initiatives
Schools	1	25	5
Univ/Colleges	5	50	20
Health	1	25	5
Religious	0	20	4
Other	0	20	4
Office	5	50	20
Food Retail	1	25	5
Other Retail	1	25	5
Hotels/Motels	1	25	5
Restaurants	0	20	4
Recreation	0	20	4
Warehouses	0	20	4

Overall Impact

The estimated annual provincial savings in electricity consumption and demand with and without initiatives to encourage the use of EVSDs are as follows:

	Maximum Possible	With Initiatives	Without Initiatives
Consumption (MWh)	971,600	358,500	102,900
Demand (MW)	223	78	21

Comments

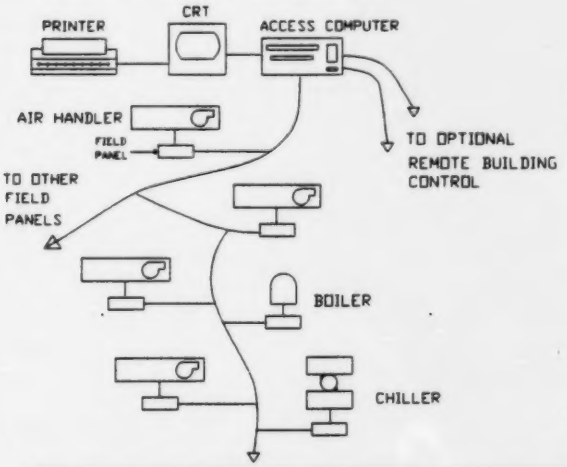
Dissemination of information on successful application of the technology is required to encourage consideration of electronic variable speed drives for specification and purchase.

ENERGY MANAGEMENT CONTROL SYSTEMS

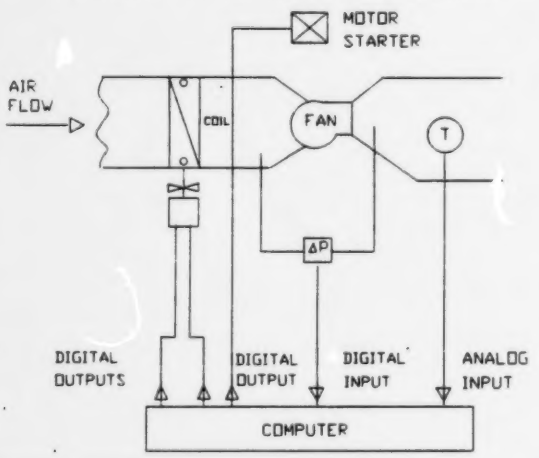
End Use: Motors

Application: New X
Retrofit X

SYSTEM CONFIGURATION



CONTROL OF AIR HANDLING EQUIPMENT



General Description

Energy Management Control Systems (EMCS) reduce energy waste through automatic control of the building's energy using systems. Typically, the EMCS controls the most energy-intensive building systems which provide heating, cooling, ventilation and lighting. Lighting automation is discussed as a separate EMCS application. The basic function of an EMCS is to provide operating cost savings by allowing the building operator to control the building systems cost effectively without affecting their normal functions or sacrificing occupant comfort.

Six basic components of an EMCS are sensors, control actuators, field termination panels, modems, communication links, and controllers. Large EMCS will utilize all components whereas small systems may not have sensors, modems or communication links.

Specifications

An EMCS can be applied to almost all new or existing commercial buildings for automating functions which otherwise would be performed manually. The value of energy savings and other benefits created by a well designed and maintained EMCS can easily justify the investment.

Capital costs for retrofitting EMCS in existing buildings are generally higher because of restrictions imposed by existing controls, and existing HVAC equipment. The cost of installation of EMCS is often quoted on a cost per connected point. Temperature sensors, stop/start a motor and a valve actuator are all examples of connected points. More than half of the average $500 per point installed cost of an EMCS is the labour required to install the points.

An EMCS can be specified and installed by control companies on a turnkey basis. This practice is common for small buildings. Large systems are often specified by a consulting engineer or building engineer using a performance specification. The building owner must define the specific objectives of the EMCS for the particular building.

Field Experience

The cost of an EMCS has declined from $1000 per installed point to $500 per installed point in recent years. Almost 80% of energy savings for EMCS in HVAC applications are derived from simple stop/start of motors. Problems with EMCS are primarily due to poorly defined objectives, vague specifications, existing HVAC system problems, inadequate software and poor operator training. The new modular electronics technology make EMCS more versatile for future expansion and operator communication. Application software and operator training are now the key issues for system selection.

Energy Savings

Energy savings for HVAC applications are related to a reduction of scheduled motor loads for fans and pumps. Savings are calculated based on current operating schedules. Case studies show a range of savings from 5% to 40% of current motor energy use. Savings of 20% are typical for most commercial buildings. Savings of 10% for heating energy and 10% for cooling energy are also typical due to the reduction of outside air (fan stop/start) and optimizing routines.

Payback Period

Energy Management Control Systems comprise several components: sensors and control points; field panels; and the central processing unit. The total cost of the components will depen on building size and functions of the system. Typically, the cost averages 30 to 40¢ per square foot or $500 to $600 per installed point.

Total energy savings also depend on building size and system functions. Payback periods typically range from 2 to 5 years.

Applicability

Percent of motor energy use to which measure applies:

Schools	Univ/Coll	Health	Religious	Other	Office	Food Retail
53	77	19	5	28	71	67

Other Retail	Hotels/Motels	Restaurants	Recreation	Warehouses
53	35	17	28	28

Barriers

The barriers preventing the more widespread use of energy management management control systems (ECMS) are:

- lack of information on their operation, performance and capabilities;
- a high real and perceived cost; and
- inadequate customer support.

A recent study by EPRI in the United States found that those building operators who had not installed EMCS had not done so because either they felt that their current method of building control was adequate or that EMCS were too expensive and would not be cost effective. This points to a lack of good documented evidence of EMCS performance and the lack of monitoring and cost savings data. It also shows that EMCS are sometimes oversold and overpriced. General awareness is high, but so also is the perceived risk.

Other barriers include the poor performance of some EMCS due to inaccurate calibration, and inadequate or overpriced support services to help the building operator use and maintain the system. In the United States, the exemption of small commercial users from demand charges also acts as a barrier, and this would also be the case in Ontario.

Penetration of Technology

The use of EMCS is much higher in large buildings and institutions than in smaller buildings in which conventional control systems and a good operating staff can often achieve as high a building efficiency as an automated system.

In the United States, the EPRI survey cited above indicated that 70% of buildings over 50,000 square feet (5000 sq.m.) now have ECMS. In Ontario the percentage is likely to be somewhat smaller because of the lower savings to be achieved from controlling

cooling equipment. In new buildings, however, the adoption rate is at least 70%. In smaller buildings, the use of ECMS in Ontario is probably low, especially for those users who do not pay demand charges (buildings with a demand of less than 50kW in most of the province). In the future, the trend towards most large buildings utilizing ECMS will continue, particularly as microprocessor costs are reduced and control software and calibration techniques improve. In smaller buildings, high ECMS utilization will depend on lower costs and simpler systems being available that can be tailored to meet the fewer timing and duty cycling requirements of these buildings. Lower cost support services must be developed for the less sophisticated building operator and there must be more demonstration, monitoring, and documentation of the performance of ECMS in Ontario.

Measures to increase the penetration in existing buildings should concentrate on documentation of successful installation and some standardization of the user interface. Building code changes requiring the installation of some form of ECMS (at least for stop/start scheduling) would be effective in ensuring continued use in all new buildings.

The following are estimates of the current stock penetration and expected penetration in 2000 with and without measures to increase the use of ECMS:

	Current Penetration	Penetration in 2000 With Initiatives	Without Initiatives
Schools	25	68	45
Univ/Colleges	35	70	55
Health	20	60	40
Religious	1	40	20
Other	10	50	30
Office	30	65	50
Food Retail	25	60	45
Other Retail	25	60	45
Hotels/Motels	15	55	35
Restaurant	10	50	30
Recreation	10	50	30
Warehouse	10	50	30

Overall Impact

The estimated annual provincial savings in electricity consumption and demand with and without measures to increase the use of ECMS is as follows:

	Maximum Possible	With Initiatives	Without Initiatives
Consumption (MWh)	1,063,000	513,000	287,000
Demand (MW)	261	125	70

Comments

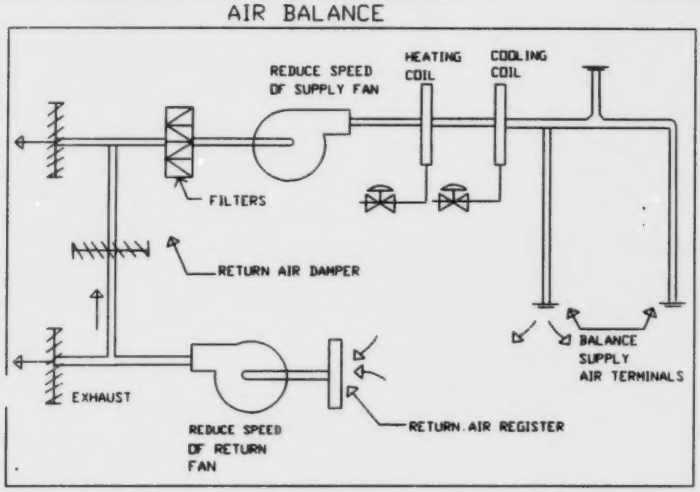
Scheduling of motor loads may not change the building peak demand. In most cases energy saved is due to decreasing energy use in the shoulder areas of daily energy use (early morning and evening).

AIR BALANCING

End Use: Motors **Application: New**

Retrofit X

AIR BALANCE



General Description

The airflow rate of an HVAC fan should be chosen to meet the total peak cooling and heating loads of the zones served, at the corresponding design supply air temperature. Actual fan airflow rates are often higher than necessary. The fan may be oversized by the original designer for a safety factor. The implementation of energy conservation measures, such as lighting reductions, may reduce the peak cooling load, and thus the airflow requirements.

Other changes in the conditioned space, such as relocation of occupants, will change the airflow requirements for each zone. The peak cooling load can be calculated for each zone, and the air supply to that zone adjusted accordingly. This is the first step in air balancing.

If the total airflow required by all zones served by the fan is lower than the fan capacity, the fan speed can be reduced. The reduction of speed requires a pulley change for fan belt-driven fans, or using a lower speed motor for direct-driven fans. The fan could also be time scheduled (often called duty cycled) to reduce airflow. Duty cycling is not recommended by most engineers.

Supply, return and exhaust fans must be adjusted to ensure that the sum of return and exhaust air is equal to the air supply volume. Otherwise, pressure differences between the building interior and exterior can result in drafts and wasted energy.

Specifications

This measure applies to constant-volume HVAC systems and to variable-air-volume (VAV) systems which use low-efficiency flow-reduction methods, such as discharge dampers or inlet vanes. The savings for VAV will not be as great as for constant volume systems. The equivalent measure for new construction is more careful fan sizing. The measure may be impossible to implement for some direct-driven fans because there are a limited number of standard motor speeds.

Engineering analysis is necessary to determine the airflow requirements for each zone.

Field Experience

The highest applicability of this measure is in office buildings, and this building sector has shown the greatest adoption to date. The savings, particularly in heating and cooling energy, quickly pay back the relatively low cost of retaining an air balancing contractor and modifying fans to reduce their speed. Heating and cooling savings are derived primarily from the reduction of outside air quantities.

Air balancing can improve occupant comfort as well as providing energy savings. It is a particularly effective measure when combined with a refinement of HVAC controls to provide a high level of comfort with greatly improved energy efficiency.

Opportunities for application are also high in hospitals and other institutions. Adoption in these sectors has lagged behind office buildings.

Energy Savings

At 100% fan efficiency, motor energy use is proportional to the cube of the fan rotational speed. Therefore, a 10% reduction in airflow rate will result in a maximum reduction in motor horsepower of 27%. Actual savings will be slightly lower, depending on each specific fan's operating characteristics. Typically, airflow rates can be reduced by about 10%, resulting in average savings of 25%.

Payback Period

The cost for an air balancing contractor's services is typically from 7 to 15¢ per square foot. Added to this cost is $50 to $500 to replace the fan sheave to slow its speed, and possibly about $1000 for engineering assistance on large, more complex systems. The total cost is generally very small compared to potential energy savings and payback period are typically in the order of 1 to 2 years, or less.

Applicability

Percent of motor energy use to which measure applies:

Schools	Food Univ/Coll	Health	Religious	Other	Office	Retail
21	32	33	5	20	35	32

Other Retail	Hotels/Motels	Restaurants	Recreation	Warehouses
25	16	15	20	10

Barriers

The barriers to the use of air balancing as a method of reducing HVAC motor electricity consumption include:

- lack of awareness of the benefits of air balancing
- the requirement for an air system audit
- insufficient documentation and performance data

In all cases, an engineering analysis or audit is required. The need for this custom analysis rather than a simpler user-selected solution is itself a barrier. There also appears to be insufficient documented performance data available for a building operator to quickly estimate the savings that could be achieved and self-specify the solution.

Penetration of Technology

Because air balancing involves the purchase of engineering expertise and only occasionally actually involves the acquisition of equipment to achieve the savings, it is difficult to define penetration in terms of sales of equipment. It is estimated that

in Ontario less than 10% of commercial and institutional buildings currently have had some form of air balancing. Without any action to increase the awareness of the benefits of air balancing, penetration is unlikely to use rise much above current levels. Penetration could be increased by documenting the savings in buildings that have balanced their HVAC systems and the development and dissemination of rules of thumb which could be used by building operators to assess the benefits of air balancing in their buildings.

The following are estimates of the current penetration and expected penetration in 2000 with and without measures to encourage more building owners to balance their air systems:

		Penetration in 2000	
	Current Penetration	With Initiatives	Without Initiatives
Schools	5	50	10
Univ/Colleges	5	50	10
Health	10	60	15
Religious	1	40	5
Other	1	40	5
Office	15	70	20
Food Retail	5	50	10
Other Retail	5	50	10
Hotel/Motel	5	50	10
Restaurant	1	40	5
Recreation	1	40	5
Warehouse	1	40	5

Overall Impact

The estimated annual provincial savings in electricity consumption

and demand with and without initiation to encourage more air balancing:

	Maximum Possible	With Initiatives	Without Initiatives
Consumption (MWh)	839,300	447,400	45,100
Demand (MW)	17	6	1

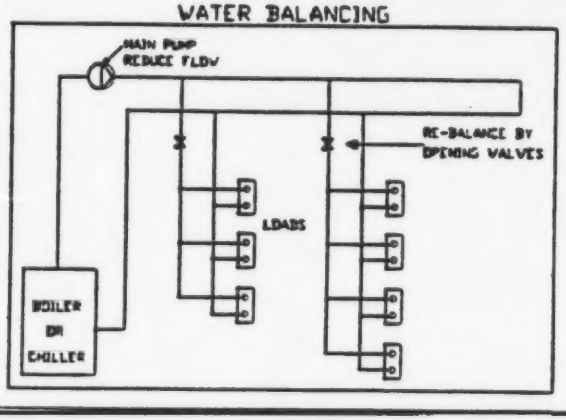
Comments

Increasing attention to the issue of interior air quality may be a barrier to acceptance of this measure. Thorough information on correct implementation and the impact on building air quality needs to be provided, in order to encourage adoption of this measure.

WATER BALANCING

End Use: Motors

Application: New
Retrofit X



General Description

Water balancing applies to a number of hydronic systems in buildings:

- hot water heating circuits
- chilled water circuits
- condenser water or cooling tower circuits.

The water flow rate of the pumps in each of these systems should be that rate which provides the design temperature rise (heating) or drop (cooling), at the design water temperature.

Actual pump flows are often higher than necessary. Pumps are often oversized for safety factor by the original system designer. Reduction in the airflow over heating and cooling coils, as the result of air balancing, reduces the water flow rate required to achieve the design temperature difference at the coil. Control changes to heating and cooling systems, to improve energy efficiency, can also reduce water flow requirements.

Moderate pump flow reductions are achieved by machining the pump impellor to reduce its diameter. Large changes in flow require pump replacement to ensure efficient operation.

Specifications

Water system balancing is carried out by a certified balancing contractor, or other experienced technician. Providing the appropriate water flow rate to each coil requires a trial and error process of valve adjustment and readings of temperature difference, pressure difference or flow rate. The actual procedure depends on the instrumentation installed in the system.

Field Experience

Water system balancing is applied infrequently as an energy saving measure. Typically, water balancing is requested to correct a comfort problem in a particular zone. Low adoption of this measure is mainly due to the relatively low magnitude of pumping energy as a component of total building electrical consumption.

Energy Savings

The power drawn by the pump motor is proportional to the cube of the flow rate. Therefore, a flow rate reduction of 5% will result in a maximum pump power reduction of about 19%.

Typical flow reductions are in the order of 5%, resulting in an average pump energy reduction of about 15%.

Payback Period

The cost of measuring and balancing building hydronic systems typically costs about 10 to 20¢ per square foot. The cost a machining the pump impellor varies according to pump size, from about $500 to $1500 per pump. Engineering assistance, if required should cost about $100 per pump.

The total cost of water balancing typically pays back in 2 to 3 years.

Applicability

Percent of motor energy use to which measure applies:

Schools	Univ/Coll	Health	Religious	Other	Office	Food Retail
4	6	7	0	2	7	2

Other Retail	Hotels/Motels	Restaurants	Recreation	Warehouses
4	3	0	2	0

Barriers

Awareness of the energy saving benefits of water balancing is generally low. Building operators seldom consider water balancing as an energy serving measure because the amount of electricity used for water pumping is usually a small percentage of total electricity use; and balancing is usually considered only to be a tool for comfort control. Expertise is also required to carry out a system audit.

Penetration of Technology

While water balancing is often used to optimize comfort conditions in commercial and institutional buildings, it is estimated that only 10% of Ontario buildings have taken steps to balance water flows specifically to save electricity (or heating fuel). More widespread use of this practice will depend on better information on its benefits being available to Ontario building managers, and some incentive being available to reduce the payback and risk of having an audit.

The following are estimates of current penetration and expected penetration in 2000 with and without measures to encourage wider use of water balancing:

	Current Penetration	Penetration in 2000 With Incentives	Penetration in 2000 Without Incentives
Schools	5	35	10
Univ/College	5	35	10
Health	10	40	15
Religious	1	30	5
Other	1	30	5
Offices	15	45	20
Food Retail	5	35	10
Other Retail	5	35	10
Hotels/Motels	5	35	10
Restaurants	1	30	5
Recreation	1	30	5
Warehouses	1	30	5

Overal Impact

The estimated annual provincial savings in electricity consumption and demand with and without measures to increase the use of water balancing are as follows:

	Maximum Possible	With Initiatives	Without Initiatives
Consumption (MWh)	75,800	25,300	4,200
Demand (MW)	17	6	1

Comments

As well as reducing pump energy use, water system balancing can result in substantial heating and/or cooling energy reductions and usually results in improved occupant comfort.

4.5.3 Motor End-Use Emerging Technologies

Emerging technologies for energy reduction in the motor end-use category relate to the application of refinements in semi-conductor technology. As production of microprocessors used to control hours of use and speed of motors increases, their cost decreases and therefore they become more widely applied.

The "power chip", when fully developed and commercialized, will allow incorporation of logic and communication circuits with line voltage circuits. This technology will have an impact on motor control technology, as well as applications such as lighting ballast control.

4.6 Total Electrical Energy Use

4.6.1 Applicable Measures and Technology

Measures in this end-use category have an impact on the total electrical energy use of the building. Technologies in this category include those which improve the efficiency with which electricity is delivered to building loads, or which reduce the cost of purchased electricity.

The measures reviewed in this category include Cogeneration and Power Factor Correction. Both of these measures are included in the database and the technology profiles.

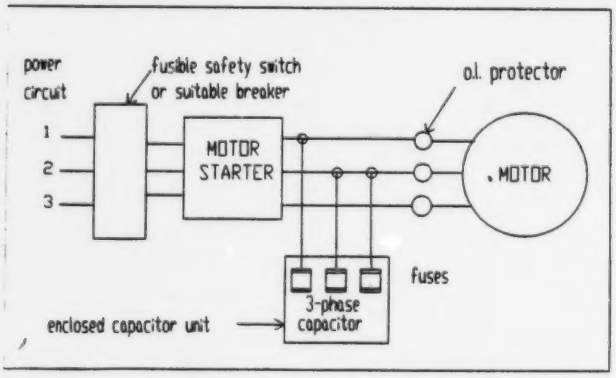
4.6.2 Total Energy Use Technology Profiles

POWER FACTOR CORRECTION

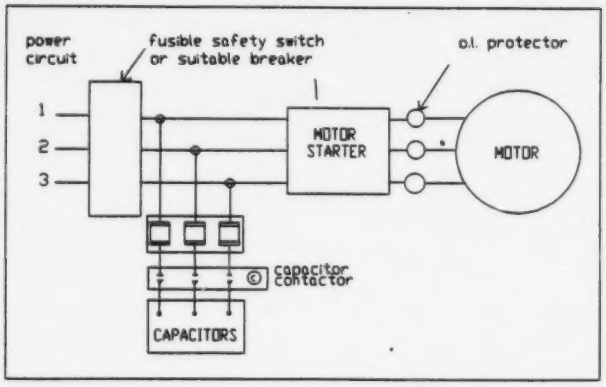
End Use: Total Electricity Use **Application: New X**

Retrofit X

FANS



CHILLERS



General Description

Electrical utilities typically charge a penalty for power factors below 0.85 or 0.9 (85 or 90%). Increasing power factor to this level will result in savings on a building's electrical bills. This can be achieved by installing capacitors. Capacitors could be installed to bring the power factor above the penalty threshold. This practice will benefit the utility by reducing system KVA load with no economic benefit to the building owner.

The total power drawn by a building's electrical systems is made up of two components: "active" power, which is capable of doing work, and "reactive" or magnetizing power, which does no work, but is necessary for electrical machinery to function.

Electrical utilities calculate power factor by dividing the peak active power for the month (kW demand) by the peak total power for the month (KVA demand).

Inductive loads such as motors, air conditioning chillers and lighting ballasts, reduce the power factor. Motors operated at low loads result in an even lower power factor. Capacitors, which have a "leading" power factor will offset the "lagging" power factor caused by inductive loads.

Specifications

Capacitors can be installed at the inductive load or at the building's electrical supply panel. For high speed, high inertia motors (e.g., chillers), it is best to install capacitors at the load, so that the capacitor and the load will be switched together. If they are not switched together, extremely high voltage, current and torque can result when the equipment is switched off, possibly causing damage.

Sizing capacitors for power factor correction is a critical task. If a capacitor is sized to provide a high power factor at low motor load, a "leading" power factor will result, when the motor is operating at full load. This is an undesirable condition. Providing a low lagging power factor under all load conditions, without over-correcting, requires a bank of multiple capacitors, with a complex switching system, to match the capacitance to the load. There is an upper limit to the amount of capacitance which can be switched with a motor. The switchgear manufacturer should be consulted before retrofitting a motor with capacitors.

Where there are very many inductive loads, it is often more economical and convenient to install capacitors at the power supply to the building. Sizing these capacitors involves an economic trade off between capacitor cost and power factor penalty savings, and depends on the existing power factor and payback criteria.

Field Experience

The opportunity for power factor correction in a specific building,

depends on the proportion of inductive and resistive loads and on how heavily motors are loaded. A typical, 5 hp standard induction motor has a power factor of 86.5% at full load and 71.6 at half load. At lower percent loads, power factor deteriorates more quickly.

Power factor correction is a fact of life in industry, where inductive loads make up a large part of the power used. There is less experience in commercial and institutional buildings, where power factors are frequently above the utility's penalty cut-off. The complexity of capacitor specification is a barrier to implementation. As well, motivation is low compared to other energy cost related measures, since the magnitude of potential savings is relatively small.

Energy Savings

Savings for power factor relate to the total electrical bill, not energy use. Demand charges will be lower for a lower power factor. Typical dollar savings for power factor correction amount to 5% of total annual electricity costs.

As well as dollar savings, power factor correction adds capacity to the building's electrical systems. Since electrical distribution must be sized for reactive as well as active power, reducing the reactive component frees up capacity. Improvement in electrical system voltage can also result from power factor correction.

The economic benefit of power factor correction extends beyond avoidance of the utility's power factor penalty charges. Power factor correction in buildings aids Ontario Hydro in reducing the KVA load on its generation and distribution system.

Ontario Hydro applies power factor correction equipment throughout the system to maintain required voltage levels and system stability. There are operational limits, however, to the amount of correction which Ontario Hydro can apply to the system. Therefore, power factor correction by users is also necessary.

The system power factor varies over time and is highest when there is the greatest load on the system. Further research is necessary to determine the benefit to Ontario Hydro for power factor correction in buildings beyond the 85 or 90% penalty threshold.

Payback Period

Installation of capacitors to correct power factor costs between $25 and $60 per KVAR of capacitance, or typically about $500 per KVA. Where the cost of electrical demand is high, the cost of capacitors can pay back in 1 to 3 years. The cost effectiveness of power factor correction is much higher for a utility than for users because new generating capacity costs about $3000 per KVA.

Applicability

Percent of total electrical energy use to which measure applies:

Schools	Univ/Coll	Health	Religious	Other	Offices	Food Retail
20	40	30	0	15	30	20

Other Retail	Hotels/Motels	Restaurants	Recreation	Warehouses
20	15	0	10	10

Barriers

Commercial and institutional building managers seldom consider motor electricity as a separate end use. Most motors are part of HVAC systems and it is the heating fuel which dominates energy use by these systems. Motors utilize up to one third of electricity in commercial and institutional buildings, however, and for larger

buildings electricity demand charges are significant. The most important barrier to the more widespread use of power factor correction equipment is therefore the lack of perception of the amount of electricity used by motors and the reduction in demand that can be achieved by power factor correction. Costs of correction equipment are not high, but savings in demand charges are also low at current rates, even in buildings with large HVAC systems. A further barrier to the adoption of power factor correction equipment in small buildings is that many types of small commercial and institutional facilities do not pay demand charges and therefore there are no savings.

Penetration of Technology

Few Ontario commercial or institutional buildings have taken steps to correct power factor. More widespread use of this measure will depend on better information on its benefits being available, and an incentive program offered by the utility. As indicated above, it is worthwhile for the utility to pay the full cost of correction (for, say, all motors greater than 10kW). Investment in power factor correction has a far greater return than investment in new generating capacity.

The following are estimates of current penetration and expected penetration in 2000 with and without incentives for power factor correction:

	Current Penetration	Penetration in 2000 With Initiatives	Without Initiatives
Schools	1	40	5
Univ/Colleges	1	50	5
Health	1	50	5
Religious	1	20	5
Other	1	20	5
Office	1	40	5
Food Retail	1	30	5
Other Retail	1	30	5
Hotels/Motels	1	40	5
Restaurants	1	30	5
Recreation	1	30	5
Warehouses	1	30	5

Overall Impact

The estimated provincial savings in electricity demand with and without measures to encourage power factor correction are as follows:

	Maximum Possible	With Initiatives	Without Initiatives
Demand (MW)	91	33	4

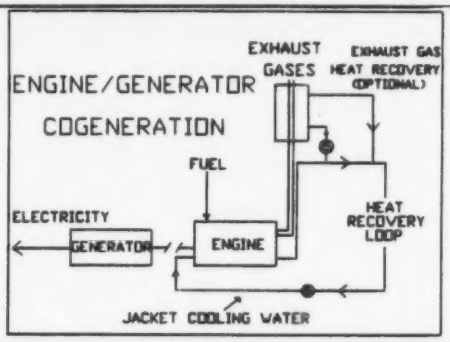
Comments

Some of the need for power factor correction in buildings can be avoided by ensuring that motors are well sized for the load.

COGENERATION

End Use: Total Electricity Use

Application: New X
Retrofit X



General Description

All commercial buidings use electricity for motors and lighting. Most of these buildings also use thermal energy for space heating, domestic hot water heating, and for processing of foods, cleaning, laundry washings, etc. In cases where both electricity and thermal energy are needed, they can be produced together economically, in a cogeneration system.

Cogeneration is defined as a method of producing electricity and useful thermal energy from one fuel source. For example, an engine/generator set can generate electricity and produce heat by recovering energy from the exhaust gases and the jacket cooling system.

The energy output of the engine/generator set is in the following proportions:

electricity	30%
jacket cooling	32%
exhaust gases	30%
losses	8%
	100%

All of the jacket cooling energy is recoverable, but only about 67% of the energy in the exhaust gas can be economically used. The average efficiency of an engine/generator set operating in a cogeneration mode is 75%.

Engine/generator cogeneration systems vary in size. They can be as small as 3 kW and as large as 6000 kW. The most economic range of this type of technology is up to 1000 kW. For larger systems, gas turbines can be used. The turbines operate similarly to engine/generator sets, but usually have lower operating efficiencies.

Steam turbines are commonly used in industry. Efficient operation of a steam turbine requires steam pressure above 300 psig. This pressure requirement limits the applicability of steam turbines in commercial buildings.

Specifications

A cogeneration system generally produces electricity and thermal energy at a fixed ratio at any given output. The thermal energy produced must be used at the time of production. If the building has access to the electricity grid, the electrical energy can be either used in site or exported to the electricity grid. The value of electricity may vary depending whether it is used on site or sold to the grid. A detailed analysis of concurrent thermal and electrical energy loads is necessary to determine the applicability and economics of cogeneration in a specific building.

Field Experience

The use of cogeneration in commercial buildings is a relatively new development. The first installations in North America were promoted by natural gas utilities between 1965 and 1975. Cogeneration development in the United States accelerated after 1978, when legislation was passed, obliging electrical utilities to purchase power from private producers, at published rates. (PURPA).

There are several packaged cogeneration units available which can provide both electricity and hot water to apartment buildings, office towers, restaurants, hotels, etc.

In Ontario, the adoption of cogeneration has been slow. There is over 400 MW of installed cogeneration capacity in the province, mostly in industrial facilities. There is approximately 5380 kW (5.4 MW) of capacity in commercial and institutional establishments:

The University of Ottawa	1600 kW
The University of Western Ontario	1600 kW
Consumers' Gas Offices	1800 kW
Municipality of Orangeville	80 kW
Erindale College	300 kW
	5380 kW

Energy Savings

Cogeneration results in a net energy input of 4000 to 5000 Btu per kWh of electricity generated. Conventional electricity generation requires about twice this amount. Cogeneration equipment produces hot water or steam at about the same efficiency (75-80%) as commercial boilers fired by natural gas. Average savings from the electricity production are 50% of total energy use.

Payback Period

The cost of cogeneration equipment applies to the incremental cost of the engine-generator set and related equipment. The cost of this equipment depends on technology selected, size of facility, fuel used and site characteristics. Typical costs are in the range of $500 to $600 per kW of capacity installed.

The incremental cost of cogeneration equipment generally pays back in 4 to 5 years.

Applicability

Percentage of total electrical energy use to which measure applies:

Schools	Univ/Coll	Health	Religious	Other	Office	Food Retail
20	51	51	0	30	20	0

Other Retail	Hotels/Motels	Restaurants	Recreation	Warehouses
2	15	5	15	0

Barriers

A recent report prepared for the Ministry of Energy reinforces the findings of previous studies and cites the following key barriers:

Institutional

- There exists a general perception among potential site developers that the current Ontario institutional framework has been inadequate. Specific evidence cited includes:
  - Ontario Hydro's historical lack of enthusiasm for cogeneration as well as the substantial costs of connecting to the grid
  - Government and Ontario Hydro's past emphasis on centralized generation
  - Existing parallel generation incentive rates emphasize the use of renewable energy whereas natural gas fired steam and gas turbines are frequently the preferred technical choice.

Economics/Risks

- Risk minimization is a major consideration of potential developers; hence the lack of adequate previous demonstration and experience with cogeneration systems in comparable facilities increases the perceived risk of cost overruns. Further, most commercial/institutional building operators do not see themselves as being "electricity producers". Cogeneration projects have to compete with other capital projects for funding and would normally only be approved when a compelling advantage was offered by the project. However, in respect of both the level of perceived risk and the typical longer payback periods offered by cogeneration projects, management approval is very difficult to obtain.

Penetation of Technology

Ontario's currently installed cogeneration capacity exceeds 400 MW; however, this installed capacity is heavily concentrated in the industrial sector.

The recent study prepared for the Ministry of Energy (cited above) estimated that an additional 569 MW of economically feasible capacity exists within the commercial/institutional sectors. However, without significant government or utility support directed towards reducing the above noted institutional, economic and risk barriers, further development of this capacity is unlikely before 2000. Only 18 MW of additional capacity is considered feasible under present conditions.

The following are estimates of current penetration and expected penetration in 2000 with and without support to encourage cogeneration:

	Current Penetration	Penetration in 2000 With Initiatives	Without Initiative
Schools	1	25	5
Univ/Colleges	2	50	10
Health	1	25	5
Religious	0	5	0
Other	0	5	0
Offices	0	15	0
Food Retail	0	5	0
Other Retail	0	5	0
Hotels/Motels	0	10	0
Restaurants	0	5	0
Recreation	0	5	0
Warehouses	0	5	0

Overall Impact

The estimated annual provincial savings in electrical savings and demand with and without measures to increase the use of cogeneration are as follows:

	Maximum Possible	With Initiatives	Without Initiatives
Consumption (MWh)	2,398,500	458,800	46,800
Demand (MW)	562	114	12

Comments

Cogeneration is a complex technology requiring the services of electrical and mechanical specialists. Under some conditions, specially trained operators are also required.

5.0 ENERGY CONSERVATION POTENTIAL

This section of the report summarizes the potential energy savings that are projected for implementation of the technologies described in the technology profiles. The energy savings estimate is followed by an assessment of the economic impact of these technologies. The types of initiatives that will be necessary to ensure significant penetration of the technologies in Ontario are discussed, and specific recommendations made.

5.1 Potential Energy Savings

Tables 5.1 through 5.6 summarize the estimated individual annual electricity consumption and demand savings that can be achieved with each of the 18 technologies in the 12 subsectors under the following conditions:

- Maximum possible (Tables 5.1 and 5.4)
- Without initiatives (Tables 5.2 and 5.5)
- With initiatives (Tables 5.3 and 5.6)

It is very important to note that the savings given in the attached Tables are not additive and also represent the savings that would occur if the mix between new and existing buildings remains unchanged. To determine the savings that might be achieved by implementing all measures, an additional algorithm would have to be added to the energy technology database which differentiates between the technologies which affect use (e.g. ECMS, air balancing, occupancy controls) and those which affect efficiency (e.g. motor efficiency, cooling efficiency).

The modelling of these complex interactions was beyond the scope of this study but could be added at a future date. At the present time, the attached Tables give an idea of the relative importance of each technology and the order of magnitude of the overall savings that might be achieved through implementation of programs to encourage adoption of the measures.

Reference to Table 5.1 indicates that the highest "maximum possible" savings can be achieved through the increased use of cogeneration, high efficiency luminaires, electronic variable speed drives, energy management systems, screw-in fluorescent lamps, air balancing and daylighting. Tables 5.2 and 5.3, however, show that the savings achievable from cogeneration, daylighting and high efficiency luminaires will not be significant unless there are specific initiatives to encourage higher adoption rates.

The estimates show that in general, the absence of incentives will result in very low adoption rates and small energy savings. The mounting of a comprehensive set of initiatives to encourage wider use of the technologies would quadruple the savings achieved. It is also significant that the greatest savings are achievable in the two major end-uses; lighting and motors - along with cogeneration.

5.2 Economic Impact

It is very difficult to assess the overall economic impact of the technologies reviewed in this report. If there were comprehensive investment in initiatives to encourage more widespread use of the technologies, energy

savings of up to 4 million MWh (subject to the cautions with respect to their non-additive nature given in Section 5.2), would be achieved. This would result in a savings of up to $200 million per year to Ontario energy users. Added to this would be the up to 1000 MW of electrical generating capacity that would have been "purchased" from this investment, avoiding the debt that could be associated with expanded capacities. Additional benefits would accrue from the industrial activity that would be required to support more widespread use of the technologies.

5.3 Policy/Program Implications

The technology review carried out for this report shows three types of initiative needed to encourage higher adoption rates:

- **Code Type Initiatives.** To be used where cost effectiveness to the user is high and regulation is relatively simple and effective. Examples include minimum COP or EER for cooling equipment and changes to the building code to include requirements covering daylighting and energy management control systems.

- **Financial Incentives.** To be used where the value to society or a utility is greater than the value to the user, current paybacks are too long, or the initial investment is large. Examples include rebates for power factor correction and energy efficient motors, loan programs to reduce the payback on some lighting and cooling technologies and innovative financing schemes for cogeneration. Financial incentives help generate awareness of energy efficient technologies and help to "prime the pump" when there is insufficient demand to support an effective industry to supply the

technology.

- **Information Programs.** To be used where awareness levels are low or there is insufficient documented performance data. Examples include; awareness programs on energy efficient lighting and cooling technologies, water and air balancing and lighting automation systems.

New buildings should receive the first attention to ensure that maximum conservation potential is built into them and to provide experience in managing demand side programs. The economics of retrofit in existing buildings will not change and can be delayed for a short period.

Existing buildings in which equipment with long lifespans is about to be replaced, for example, motors and cooling equipment, should also be addressed as soon as possible. This is particularly true with cooling equipment, where units installed in early HVAC systems (1950's and 1960's) are due for replacement or upgrade in the late 1980's and early 1990's.

When considering which subsectors to focus on in any program, it is important to look at hours of use. Payback for efficient lighting equipment in retail stores, for example, can be much shorter than in schools. On the other hand, lighting automation and switching systems will be much more cost effective in schools and offices where occupancy rates are much lower than in the retail subsector.

Programs must also consider how different building owners purchase energy using equipment. An initiative directed

at retail stores encouraging them to use energy efficient lamps will be ineffective if wholesalers, distributors and bulk buyers of lamps, such as school boards, are not targeted first.

It is also very important to realize that outside of major cities such as Toronto and Ottawa, there is virtually no knowledge of energy efficient products, and currently no easy way for building operators to become aware of the options. Programs must target both the product distribution networks which serve the province and the building operators in small cities and towns across the province.

Figure 5.1 Electric Energy Savings Potential in Ontario (MWh)
Maximum Potential Attainable

Measure	Schools	Univ Colleges	Health	Religious	Other	Office	Food Retail	Other Retail	Hotels Motels	Restaurants	Recreation	Warehouses	All Sub-Sectors
High Efficiency Central Cooling	938	22218	27322	87	9818	73005	2562	17165	10596	794	1114	312	165932
High Efficiency Unitary Cooling	4384	8639	4854	1401	19666	48670	12819	49474	9080	15494	2232	14486	191198
Low Wattage Per Incandescent	2699	753	800	8353	1763	18252	2514	59239	3160	32210	3253	2557	135535
Screw-In Fluorescent	36260	12424	12872	64971	13217	144541	19893	460287	40453	125235	12998	20289	963439
Energy Efficient Fluorescent	28689	24675	42367	3721	18765	286787	39509	98819	5779	7143	23369	20309	599932
Energy Efficient Ballasts	37292	29950	51441	4650	24391	348127	47998	120624	6929	10775	27675	26123	735975
High Efficiency Luminaires	60260	49344	53028	6497	32874	573517	88983	192339	20248	12654	45237	91430	1226412
Light Switching	8609	10575	9073	1395	11250	154865	8466	49497	5197	10752	11927	8699	290306
Lighting Automation	1136	7043	12086	0	3780	286869	5689	22116	2328	7218	3718	17433	369416
Occupancy Lighting Controls	80354	37012	21171	3249	19688	286787	9877	38396	16168	0	19362	60893	592957
Daylighting	86094	35214	15243	0	9450	410618	14209	109428	0	0	19445	116087	815788
Energy Efficient Motors	17153	17937	28747	3950	34875	219164	100612	84666	23286	9708	24431	15798	580326
Variable Speed Drives	22626	41101	30788	0	24911	500904	216309	73289	30684	0	17452	13542	971606
Energy Management Control System	30152	34164	15437	1140	41551	416317	239696	193420	30692	8338	29110	22589	1062605
Air Balancing	18899	25648	38450	1425	41514	312414	179802	151113	19192	10435	29084	11284	839261
Water Balancing	2257	3068	4642	0	2466	37702	7169	14479	2332	0	1728	0	75844
Power Factor Correction	0	0	0	0	0	0	0	0	0	0	0	0	0
Cogeneration	146271	298963	407188	0	291054	980361	0	56884	89635	50455	77728	0	2398537

Figure 5.2 Electric Energy Savings Potential in Ontario (MWh)
Potential Attainable by the year 2000 without Initiatives

Measure	Schools	Univ Colleges	Health	Religious	Other	Office	Food Retail	Other Retail	Hotels Motels	Restaurants	Recreation	Warehouses	All Sub-Sectors
High Efficiency Central Cooling	104	2469	3036	10	1091	8112	285	1907	1177	88	124	35	18437
High Efficiency Unitary Cooling	244	480	270	78	1093	2704	712	2749	504	861	124	805	10622
Low Wattage Par Incandescent	426	159	188	253	278	6084	559	29619	1164	5916	597	209	45453
Screw-In Fluorescent	3817	1308	271	1313	1391	32120	7329	255715	2247	2637	274	1035	309456
Energy Efficient Fluorescent	13241	7711	9969	392	3128	89621	12346	30881	963	752	3690	4779	177472
Energy Efficient Ballasts	3044	2445	2078	188	986	43067	1939	9847	280	435	1118	1055	66483
High Efficiency Luminaires	5478	4486	4821	591	2989	52138	8089	17485	1841	1150	4112	8312	111492
Light Switching	0	0	0	0	1406	29037	1587	6187	433	768	852	1087	41358
Lighting Automation	126	783	1343	0	420	31874	632	2457	259	802	413	1937	41046
Occupancy Lighting Controls	4018	1851	1059	162	984	14339	494	1920	808	0	968	3045	29648
Daylighting	5381	783	339	0	210	8645	299	2304	0	0	409	6829	25198
Energy Efficient Motors	1400	2219	3556	197	1744	27113	4065	3421	941	392	987	638	46674
Variable Speed Drives	914	6490	1244	0	996	79090	8740	2961	1240	0	698	542	102915
Energy Management Control System	8041	10512	3859	219	9234	118948	63919	51579	7222	1853	6469	5020	286872
Air Balancing	995	1350	2136	58	1677	18377	9463	7953	1010	422	1175	456	45072
Water Balancing	119	161	258	0	100	2218	377	762	123	0	70	0	4188
Power Factor Correction	0	0	0	0	0	0	0	0	0	0	0	0	0
Cogeneration	5910	24405	16452	0	0	0	0	0	0	0	0	0	46767

Figure 5.3 Electric Energy Savings Potential in Ontario (MWh)
Potential Attainable by the Year 2000 with an Incentive Program

Measure	Schools	Univ Colleges	Health	Religious	Other	Office	Food Retail	Other Retail	Hotels Motels	Restaurants	Recreation	Warehouses	All Sub-Sectors
High Efficiency Central Cooling	313	7406	9107	29	3273	24335	854	5722	3532	265	371	104	55311
High Efficiency Unitary Cooling	1461	2880	1618	467	6555	16223	4273	16491	3027	5165	744	4829	63733
Low Wattage Par Incandescent	710	278	310	422	464	10140	978	51834	1829	9203	929	339	77437
Screw-In Fluorescent	7634	2615	677	2625	2783	48180	11517	409144	6742	6591	684	1656	500849
Energy Efficient Fluorescent	22069	15422	22429	783	6255	179242	24693	61762	1926	1504	7380	10752	354217
Energy Efficient Ballasts	8752	7029	9872	892	7145	61012	11636	22155	1330	2068	5311	5013	142217
High Efficiency Luminaires	14608	11962	12855	1575	7970	139035	21572	46628	4909	3068	10967	22165	297312
Light Switching	0	0	0	0	4219	58074	3175	18562	866	3072	2556	3262	93785
Lighting Automation	379	2348	4029	0	1260	95623	1896	7372	776	2406	1239	5811	123139
Occupancy Lighting Controls	20089	9253	5293	812	4922	71697	2469	9599	4042	0	4841	15223	148239
Daylighting	32285	5869	2541	0	1575	64834	2244	17278	0	0	3070	34143	163839
Energy Efficient Motors	4901	8691	13929	987	8719	106193	24391	20525	5645	2353	5923	3830	206087
Variable Speed Drives	5485	19469	7464	0	4982	237270	52438	17767	7438	0	3490	2708	358513
Energy Management Control System	16081	18396	7718	449	18467	208158	111858	90263	14443	3706	12938	10039	512517
Air Balancing	8952	12149	21361	561	16354	202151	85169	71580	9091	4111	11457	4445	447382
Water Balancing	713	969	1547	0	722	13307	2264	4572	736	0	506	0	25337
Power Factor Correction	0	0	0	0	0	0	0	0	0	0	0	0	0
Cogeneration	35460	146431	98712	0	14553	147054	0	5688	4482	2523	3886	0	458788

Figure 5.4 Electric Demand Savings Potential in Ontario (MW)
Maximum Potential Attainable

Measure	Schools	Univ Colleges	Health	Religious	Other	Office	Food Retail	Other Retail	Hotels Motels	Restaurants	Recreation	Warehouses	All Sub-Sectors
High Efficiency Central Cooling	1	25	9	0	6	56	1	10	5	0	1	0	115
High Efficiency Unitary Cooling	5	10	2	2	11	37	7	28	4	9	3	17	134
Low Wattage Par Incandescent	1	0	0	3	0	5	1	19	1	7	1	1	39
Screw-In Fluorescent	12	4	2	25	2	41	6	150	10	26	3	7	289
Energy Efficient Fluorescent	9	8	8	1	3	82	13	32	1	1	5	7	171
Energy Efficient Ballasts	12	9	10	2	3	99	16	39	2	2	6	9	210
High Efficiency Luminaires	20	16	10	2	5	164	29	63	5	3	10	30	356
Light Switching	3	3	2	1	2	44	3	16	1	2	3	3	82
Lighting Automation	0	2	2	0	1	82	2	7	1	1	1	6	105
Occupancy Lighting Controls	26	12	4	1	3	82	3	13	4	0	4	20	172
Daylighting	28	11	3	0	1	117	5	36	0	0	4	38	243
Energy Efficient Motors	5	4	4	1	5	42	31	28	5	2	6	4	135
Variable Speed Drives	6	9	5	0	4	95	67	24	6	0	4	3	223
Energy Management Control System	9	8	2	0	6	79	74	63	6	2	7	5	261
Air Balancing	5	6	6	0	6	59	55	49	4	2	7	3	203
Water Balancing	1	1	1	0	0	7	2	5	0	0	0	0	17
Power Factor Correction	5	7	4	0	2	37	12	19	2	0	1	2	91
Cogeneration	48	85	72	0	42	249	0	19	21	10	18	0	562

Figure 5.5 Electric Demand Savings Potential in Ontario (MW)
Potential Attainable by the Year 2000 without Initiatives

Measure	Schools	Univ Colleges	Health	Religious	Other	Office	Food Retail	Other Retail	Hotels Motels	Restaurants	Recreation	Warehouses	All Sub-Sectors
High Efficiency Central Cooling	0	3	1	0	1	5	0	1	1	0	0	0	13
High Efficiency Unitary Cooling	0	1	0	0	1	2	0	2	0	0	0	1	7
Low Wattage Per Incandescent	0	0	0	0	0	2	0	10	0	1	0	0	14
Screw-In Fluorescent	1	0	0	0	0	9	2	83	1	1	0	0	99
Energy Efficient Fluorescent	4	2	2	0	0	26	4	10	0	0	1	2	52
Energy Efficient Ballasts	1	1	0	0	0	12	1	3	0	0	0	0	19
High Efficiency Luminaires	2	1	1	0	0	15	3	6	0	0	1	3	32
Light Switching	0	0	0	0	0	8	1	2	0	0	0	0	12
Lighting Automation	0	0	0	0	0	9	0	1	0	0	0	1	12
Occupancy Lighting Controls	1	1	0	0	0	4	0	1	0	0	0	1	9
Daylighting	2	0	0	0	0	2	0	1	0	0	0	2	8
Energy Efficient Motors	0	1	1	0	0	5	1	1	0	0	0	0	10
Variable Speed Drives	0	1	0	0	0	15	3	1	0	0	0	0	21
Energy Management Control System	2	2	1	0	1	23	20	17	1	0	1	1	70
Air Balancing	0	0	0	0	0	3	3	3	0	0	0	0	11
Water Balancing	0	0	0	0	0	0	0	0	0	0	0	0	1
Power Factor Correction	0	0	0	0	0	2	0	1	0	0	0	0	4
Cogeneration	2	7	3	0	0	0	0	0	0	0	0	0	12

Figure 5.6 Electric Demand Savings Potential in Ontario (MW)
Potential Attainable by the Year 2000 with Initiatives

Measure	Schools	Univ Colleges	Health	Religious	Other	Office	Food Retail	Other Retail	Hotels Motels	Restaurants	Recreation	Warehouses	All Sub-Sectors
High Efficiency Central Cooling	0	8	3	0	2	19	0	3	2	0	0	0	38
High Efficiency Unitary Cooling	2	3	1	1	4	12	2	9	1	3	1	6	45
Low Wattage Par Incandescent	0	0	0	0	0	3	0	17	0	2	0	0	23
Screw-In Fluorescent	2	1	0	1	0	14	4	133	2	1	0	1	160
Energy Efficient Fluorescent	7	5	4	0	1	51	8	20	0	0	2	4	103
Energy Efficient Ballasts	3	2	2	0	1	17	4	7	0	0	1	2	40
High Efficiency Luminaires	5	4	2	1	1	40	7	15	1	1	3	7	86
Light Switching	0	0	0	0	1	17	1	6	0	1	1	1	27
Lighting Automation	0	1	1	0	0	27	1	2	0	0	0	2	35
Occupancy Lighting Controls	7	3	1	0	1	20	1	3	1	0	1	5	43
Daylighting	11	2	0	0	0	19	1	6	0	0	1	11	50
Energy Efficient Motors	1	2	2	0	1	20	8	7	1	0	1	1	45
Variable Speed Drives	2	4	1	0	1	45	16	6	2	0	1	1	78
Energy Management Control System	5	4	1	0	3	40	35	29	3	1	3	2	125
Air Balancing	3	3	3	0	2	38	26	23	2	1	3	1	105
Water Balancing	0	0	0	0	0	3	1	1	0	0	0	0	6
Power Factor Correction	2	3	2	0	0	15	3	5	1	0	0	1	33
Cogeneration	12	42	17	0	2	37	0	2	1	0	1	0	114

6.0 CONCLUSIONS

6.1 Technologies and Conservation Potential

The technologies reviewed in this study show considerable conservation potential in the commercial/institutional building sector. Specific conclusions concerning the technologies and the conservation potential are summarized below:

1. Lighting and motor technologies have the greatest energy savings and demand savings potential.

2. The energy technology profile model developed in this report quantified the technology variables necessary to assess the potential energy savings by end use and by commercial building sector.

3. The technology barriers can be quantified in terms of penetration rates for each commercial sector at any point in time.

4. The penetration rate of each technology is strongly influenced by the life of the technology hardware. For example, luminaires have a typical life of 20 years in most commercial buildings whereas fluorescent tubes have a life of 5 years.

5. Some technologies such as air balancing show excellent potential; however, the technology potential can only be fully realized with awareness/incentive programs.

6. The technologies can be subdivided into three groups:

    1. System related technologies (not

affected by life of equipment considerations)

2. Equipment technology with short life (less than 10 years).
3. Equipment technology with long life (more than 10 years).

7. The conservation potential is greatest in the office and retail sectors with over 70% of the total conservation potential. The office sector alone represents over 40% of the total potential savings.

8. The estimation of maximum conservation potential is based on good documentation for both percentage energy savings for each technology and the end use of energy affected in each sector. More work is required to document the Application Factors (A) for each technology. More work is required to define the current penetration rate of the technology P_c and the estimation of P for future years (with or without incentives). The investigative work should be focussed on the most promising technologies and the sectors with the best potential savings.

9. The incentive programs designed to achieve the conservation potential should be linked to the energy saving and demand reduction for electricity. The programs must attempt to quantify the savings.

10. An effective monitoring program is essential to the successful implementation of conservation measures. In the case of new buildings the

program may take the form of a review of first year energy use and a commissioning report. For existing buildings the monitoring program can be conducted using utility meters or a computer based energy accounting program.

6.2 Building Characteristics

The July 1987 report from the Ministry of Energy titled Ontario's Future Electricity Demand concludes that the electricity consumption growth rate in the commercial/ institutional sector is 2.6% per year. The report also concludes that the provincial growth rate of 2.3% per year will mean a 40% increase in consumption by the year 2000. The data analyzed in this report show similar trends in the building floor space rate of growth.

Specific conclusions related to building characteristics are summarized below:

1. New buildings will be a very significant factor in the total energy consumption by the year 2000. A projected total of 46% of the floor space will be post 1985 construction. This figure includes renovated floor space.

2. New buildings offer conservation potential which must be realized at the time of building design. Otherwise the economic opportunity may be lost until the life of building systems expire. New building conservation programs, therefore, should receive a higher priority than existing building retrofit programs.

3. No good documentation is currently available on new building energy consumption trends. More work is needed to define the profile of energy use for new buildings. Work should be focussed on building sectors with high growth rates and good conservation potential.

4. The highest growth rate of new buildings will occur in the service oriented sectors: office, retail, hotel/motel and restaurants. The greatest conservation potential likely will be found in new office and new retail buildings.

6.3 Barriers to Energy Conservation

The common barriers associated with the realization of conservation potential are:

1. Awareness and knowledge of the technology.

2. Capital for the implementation of measures.

3. Financial return on investment does not meet energy user criteria for acceptance.

4. Technologies which are related to long life equipment are changed only at replacement of equipment.

5. Investment decisions are made based on first cost, not life cycle cost.

6. Mechanisms for good technology transfer are not well understood by energy users, utility

consultants and government.

6.4 Demand Side Conservation Programs

The report provides detailed information on the conservation potential of eighteen technologies and reviews a database model for organizing the energy information. The information reviewed in this report provides some clear implications for future work in demand side conservation programs:

1. Information and the organization of the information is critical to the design planning, implementation and monitoring of future demand side programs.

2. Planners (EMR, MOE), utilities (Ontario Hydro, municipal) and consultants should develop common models to organize the information.

3. A clear distinction emerges between new and existing buildings. New buildings (in design) provide the greatest immediate need for demand side programs.

4. Demand side programs involve a learning curve for energy users, consultants, governments and utilities. The learning curve cannot be avoided. Pilot programs can be used to focus on the problems and opportunities. There is no substitute for field experience.

5. Technology transfer is a fundamental part of any demand side program. The awareness

and knowledge barriers must be addressed by demand side programs.

7.0 RECOMMENDATIONS

7.1 Energy Information Database

The concept of the Energy Technology Database outlined in this report provides a good framework for the development of energy conservation estimates. Unlike previous attempts which use the typical building concept for conservation estimates, the database model provides a better overview of energy savings potential.

The Energy Technology Database should be reviewed with potential users to determine specific needs. Assuming the database tool is perceived as an asset to planners and policymakers, the Ministry should make a strong commitment to support the database and manage the information in the database. A development plan for the database is recommended to organize the efforts of potential database users.

7.2 New and Renovated Buildings

New buildings and newly renovated buildings provide the best potential for energy conservation in commercial buildings. Many conservation measures for new buildings are cost effective if applied during the design phase (but are not cost effective for retrofit). The Ministry of Energy needs to define policies for new buildings to address the barriers to conservation and provide legislation and/or incentives to realize the savings.

Task Force

Formulation of a task force is recommended to address the issue of new building conservation. Representatives should be taken from the Ministry of Energy, Ontario Hydro, Building Owners and Designers of Buildings. The task force must have a clear mandate to provide recommendations on new building measures and a deadline to

produce their report.

The proposed Task Force would have two roles. First, to make recommendations on new and renovated building measures and second, to educate the member's constituency on the options and potential for energy efficient technology and measures. Membership should be drawn from building designers, developers, architects and engineers, government ministries responsible for energy and building codes, and from Ontario Hydro and local utilities.

Ontario Hydro

Ontario Hydro should launch pilot incentive programs for new building measures as soon as possible. Office and retail sectors represent the largest electricity users and therefore the best targets for incentive programs. An example of a pilot program could be EE motor rebates for new commercial buildings in the Thunder Bay area.

The programs would pay the difference in cost between standard and high efficiency/peak reduction equipment in new and renovated buildings. The program should be launched as a pilot program as soon as possible, being extended rapidly to all areas and being publicized among associations of building architects, designers, developers and engineers, and building permit offices throughout Ontario.

Energy Analysis Research

The conservation potential for new buildings and renovated buildings is not estimated in this report. No concise data is available for estimating the potential. A project should be initiated to review the potential in typical new buildings. Office and retail buildings are suggested for this project since these building types

represent the major growth areas in new buildings.

Code Upgrading

The Ontario Commercial Building Code should be closely analyzed to determine how it could be used to ensure minimum efficiency equipment is specified in all new and renovated buildings. Prescriptive codes which specify minimum levels of efficiency and maximum peak demand, are proposed as one alternative for consideration.

In a similar manner, Ontario Hydro should require that equipment with a certain minimum level of efficiency will be used in a new or renovated building before electrical supply is connected.

EE Technology/Industrial Development Program

Research and development support should be provided to Ontario industries which develop and manufacturer energy efficient technologies for new or renovated commercial and institutional buildings. An energy efficient product development centre run jointly by government and industry should be considered, with the objective of making energy efficient products widely available in the province and providing economic development and export opportunities.

7.3 Existing Buildings

The Energy Technology Database shows the potential for conservation by measure and by sector. The Ministry of Energy should target their policy and programs to maximize the benefits for a given level of effort. Office and retail sectors provide the best targets with over 70% of the potential demand savings with an initiative program.

The policy and programs must be measure specific in order

to encourage conservation activity. Measures such as cogeneration and power factor correction require utility sponsors whereas measures like energy management control systems can be encouraged with information programs.

Information Programs

An information and technology transfer program covering all of the energy efficient commercial/institutional building technologies covered in this study should be developed as soon as possible. It should address in particular the needs of the building operators outside of the Toronto and Ottawa areas. It should be delivered by local utilities and equipment distributors.

Rebate Programs

Rebate programs for energy efficient lighting equipment, motors and power factor correction should replace current pilot programs as soon as possible. The size of the rebate should be based on experience in the United States and the time frame required for efficient technologies to have an impact on electricity demand as set out in this study and in more detailed market penetration studies.

Energy Service Program

Ontario Hydro should initiate a program under which it acts as a broker for the installation of energy efficient technologies by energy services companies. This program should particularly target large institutional and commercial users and cover technologies with high initial cost such as cogeneration and installation of building automation systems.

7.4 Specific Initiatives for Priority Technologies

Lighting and motors represent the largest potential for conservation of electricity use. Specific programs

recommended to address these technologies are summarized below:

Demonstration Program

These demonstrations should concentrate on lighting technologies such as electronic ballasts and lighting automation systems which have had limited exposure in Ontario to date.

Documentation and Technology Transfer Program

Many examples of energy efficient lighting are in use in Ontario buildings but little is known about them outside of major centres. This program should document the performance of actual lighting technology and produce case study and other materials for distribution by building associations, permit offices, local utilities, and regional equipment distributors.

This program should also document the performance of high efficiency motors, electronic variable speed drives, air and water balancing, and unitary equipment which use high efficiency motors and drives. Case study and other information on the technologies, measures, and performance results should be prepared and circulated widely through building associations, permit offices, local utilities, and equipment distributors.

Innovative Lease Arrangements

Model leases for landlord/tenant agreements that would fairly apportion the costs and benefits of energy efficient equipment investments should be developed and circulated widely, with appropriate explanations, through organizations such as BOMA and landlord and tenant organizations.

Model Tender Documents

Model tender documents for the purchase of energy efficient equipment that emphasize life cycle cost rather than first cost, should be developed and circulated widely to building designers, engineers, and owners.

Lighting Rebate Program

Ontario Hydro should institute a lighting equipment rebate program covering lamps, ballasts and controls as soon as possible. The rebate program should apply to specified types of ballasts or controls and to lamps above a minimum lumens per watt performance.

Motor Rebate Program

Ontario Hydro's current pilot high efficiency motor rebate program should be expanded to include all motors purchased directly or through motor distributors. Alternative approaches for providing rebates on motors purchased by OEMs should be investigated.

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APPENDIX B

ENERGY TECHNOLOGY DATABASE

Applicability Factor, A - Percent of End -use Energy to which Measure Applies

Measure	% Savings	Schools	Univ Colleges	Health	Religious	Other	Office	Food Retail	Other Retail	Hotels Motels	Restaurants	Recreation	Warehouses
High Efficiency Central Cooling	18	11	67	83	2	22	50	11	17	39	2	22	1
High Efficiency Unitary Cooling	12	78	39	22	53	67	50	83	72	50	64	67	77
Low Wattage Par Incandescent	45	1	1	0	10	1	1	1	8	3	10	2	1
Screw-In Fluorescent	70	10	5	3	51	5	6	5	33	28	26	5	5
Energy Efficient Fluorescent	10	77	88	82	21	56	88	88	56	28	11	67	41
Energy Efficient Ballasts	10	66	87	86	25	66	88	86	56	30	15	76	46
High Efficiency Luminaires	35	30	40	25	10	25	40	46	25	25	5	35	46
Light Switching	15	50	50	25	17	25	32	13	19	25	14	31	13
Lighting Automation	20	1	11	11	0	6	39	6	6	6	6	6	17
Occupancy Lighting Controls	35	40	30	10	5	15	20	5	5	20	0	15	30
Daylighting	50	38	22	6	0	6	21	5	11	0	0	11	47
Energy Efficient Motors	7	66	77	83	50	60	78	61	51	66	51	61	51
Variable Speed Drives	60	10	21	10	0	5	21	15	5	10	0	5	5
Energy Management Control System	20	53	77	19	5	28	71	67	53	35	17	28	28
Air Balancing	25	21	32	33	5	20	35	32	26	16	15	20	10
Water Balancing	15	4	6	7	0	2	7	2	4	3	0	2	0
Power Factor Correction	5	20	40	30	0	15	30	20	20	15	0	10	10
Cogeneration	50	20	51	51	0	30	20	0	2	15	5	15	0

Current Penetration of Technology, Pc (%) - Percent of each Measure found in Current Building Stock

Measure	Schools	Univ Colleges	Health	Religious	Other	Office	Food Retail	Other Retail	Hotels Motels	Restaurants	Recreation	Warehouses
High Efficiency Central Cooling	10	10	10	10	10	10	10	10	10	10	10	10
High Efficiency Unitary Cooling	10	10	10	10	10	10	10	10	10	10	10	10
Low Wattage Par Incandescent	5	5	2	1	5	10	10	20	5	2	2	2
Screw-In Fluorescent	5	5	5	1	5	10	5	10	10	5	5	2
Energy Efficient Fluorescent	35	20	15	5	10	20	20	20	10	5	10	15
Energy Efficient Ballasts	2	2	1	1	1	3	1	2	1	1	1	1
High Efficiency Luminaires	1	1	1	1	1	1	1	1	1	1	1	1
Light Switching	80	60	60	70	20	20	20	20	40	30	35	20
Lighting Automation	10	10	10	0	10	10	10	10	10	10	10	10
Occupancy Lighting Controls	0	0	0	0	0	0	0	0	0	0	0	0
Daylighting	20	10	10	0	10	5	5	5	10	5	10	15
Energy Efficient Motors	2	3	3	0	0	3	1	1	1	1	1	1
Variable Speed Drives	1	5	1	0	0	5	1	1	1	0	0	0
Energy Management Control System	25	35	20	1	10	30	25	25	15	10	10	10
Air Balancing	5	5	10	1	1	15	5	5	5	1	1	1
Water Balancing	5	5	10	1	1	15	5	5	5	1	1	1
Power Factor Correction	1	1	1	1	1	1	1	1	1	1	1	1
Cogeneration	1	2	1	0	0	0	0	0	0	0	0	0

Penetration of Technology in the Year 2000
without Initiatives, P (%) - Percent of each Measure found in 2000 Building Stock

Measure	Schools	Univ Colleges	Health	Religious	Other	Office	Food Retail	Other Retail	Hotels Motels	Restaurants	Recreation	Warehouses
High Efficiency Central Cooling	20	20	20	20	20	20	20	20	20	20	20	20
High Efficiency Unitary Cooling	15	15	15	15	15	15	15	15	15	15	15	15
Low Wattage Par Incandescent	20	25	25	4	20	40	30	60	40	20	20	10
Screw-In Fluorescent	15	15	7	3	15	30	40	60	15	7	7	7
Energy Efficient Fluorescent	65	45	35	15	25	45	45	45	25	15	25	35
Energy Efficient Ballasts	10	10	5	5	5	15	5	10	5	5	5	5
High Efficiency Luminaires	10	10	10	10	10	10	10	10	10	10	10	10
Light Switching	80	60	60	70	30	35	35	30	45	35	40	30
Lighting Automation	20	20	20	5	20	20	20	20	20	20	20	20
Occupancy Lighting Controls	5	5	5	5	5	5	5	5	5	5	5	5
Daylighting	25	12	12	5	12	7	7	7	12	7	12	20
Energy Efficient Motors	10	15	15	5	5	15	5	5	5	5	5	5
Variable Speed Drives	5	20	5	4	4	20	5	5	5	4	4	4
Energy Management Control System	45	55	40	20	30	50	45	45	35	30	30	30
Air Balancing	10	10	15	5	5	20	10	10	10	5	5	5
Water Balancing	10	10	15	5	5	20	10	10	10	5	5	5
Power Factor Correction	5	5	5	5	5	5	5	5	5	5	5	5
Cogeneration	5	10	5	0	0	0	0	0	0	0	0	0

Penetration of Technology in the Year 2000
with Initiative , P' (%) Percent of each Measure found in 2000 Stock

Measure	Schools	Univ Colleges	Health	Religious	Other	Office	Food Retail	Other Retail	Hotels Motels	Restaurants	Recreation	Warehouses
High Efficiency Central Cooling	40	40	40	40	40	40	40	40	40	40	40	40
High Efficiency Unitary Cooling	40	40	40	40	40	40	40	40	40	40	40	40
Low Wattage Par Incandescent	30	40	40	6	30	60	45	90	60	30	30	15
Screw-In Fluorescent	25	25	10	5	25	40	60	90	25	10	10	10
Energy Efficient Fluorescent	85	70	60	25	40	70	70	70	40	25	40	60
Energy Efficient Ballasts	25	25	20	20	30	20	25	20	20	20	20	20
High Efficiency Luminaires	25	25	25	25	25	25	25	25	25	25	25	25
Light Switching	80	60	60	70	50	50	50	50	50	50	50	50
Lighting Automation	40	40	40	10	40	40	40	40	40	40	40	40
Occupancy Lighting Controls	25	25	25	25	25	25	25	25	25	25	25	25
Daylighting	50	25	25	10	25	20	20	20	25	20	25	40
Energy Efficient Motors	30	50	50	25	25	50	25	25	25	25	25	25
Variable Speed Drives	25	50	25	20	20	50	25	25	25	20	20	20
Energy Management Control System	65	70	60	40	50	65	60	60	55	50	50	50
Air Balancing	50	50	60	40	40	70	50	50	50	40	40	40
Water Balancing	35	35	40	30	30	45	35	35	35	30	30	30
Power Factor Correction	40	50	50	20	20	40	30	30	40	30	30	30
Cogeneration	25	50	25	5	5	15	5	10	5	5	5	5

Average Load Factor by End Use (%) for Measure and Sub-sector

Measure	Schools	Univ Colleges	Health	Religious	Other	Office	Food Retail	Other Retail	Hotels Motels	Restaurants	Recreation	Warehouses
High Efficiency Central Cooling	10	10	35	10	20	15	20	20	25	20	10	10
High Efficiency Unitary Cooling	10	10	35	10	20	15	20	20	25	20	10	10
Low Wattage Par Incandescent	35	36	60	30	80	40	35	35	45	55	50	35
Screw-In Fluorescent	35	36	60	30	80	40	35	35	45	55	50	35
Energy Efficient Fluorescent	35	36	60	30	80	40	35	35	45	55	50	35
Energy Efficient Ballasts	35	36	60	30	80	40	35	35	45	55	50	35
High Efficiency Luminaires	35	36	60	30	80	40	35	35	45	55	50	35
Light Switching	35	36	60	30	80	40	35	35	45	55	50	35
Lighting Automation	35	36	60	30	80	40	35	35	45	55	50	35
Occupancy Lighting Controls	35	36	60	30	80	40	35	35	45	55	50	35
Daylighting	35	36	60	30	80	40	35	35	45	55	50	35
Energy Efficient Motors	40	50	75	50	80	60	37	35	55	60	50	50
Variable Speed Drives	40	50	75	50	80	60	37	35	55	60	50	50
Energy Management Control System	40	50	75	50	80	60	37	35	55	60	50	50
Air Balancing	40	50	75	50	80	60	37	35	55	60	50	50
Water Balancing	40	50	75	50	80	60	37	35	55	60	50	50
Power Factor Correction	35	40	65	35	80	45	35	35	48	58	50	35
Cogeneration	35	40	65	35	80	45	35	35	48	58	50	35